A REVIEW OF THE USE OF HERBICIDES IN BRITISH VEGETABLE PRODUCTION

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THE production of vegetables for market, for canning or for freezing, is an important industry in Great Britain, where some twenty different crops are grown on a large scale and others are produced on smaller acreages by specialist growers. In general, these crops bring in a considerably higher return per acre than typical farm crops, and traditional methods of vegetable culture have always depended to a large extent on the use of hand labour. While it is generally appreciated that sound rotational principles and good husbandry are still basically important in ensuring clean crops of high quality, it is not surprising that with the scarcity and high cost of hand labour there should be an increasing demand by vegetable growers for chemical methods of weed control. During the past decade, several chemicals have been introduced which have proved valuable in certain crops, but it is clear that much further research is needed if effective herbicides for use in many of the others are to be developed. In the present paper, British work on herbicides for vegetable crops is briefly reviewed and an attempt made to assess how far the demand for chemical weed-control methods has been met.

Weed Problems in Vegetable Crops

The greatest problem is presented by annual weeds, of which *Stellaria media* (L.) Vill., *Urtica urens* L., *Chenopodium album* agg., and *Poa annua* L. are generally considered to be the most serious. *U. urens* and *C. album* are usually restricted to spring-sown crops, while *S. media* and *P. annua* can germinate and grow throughout the year and are especially troublesome in crops such as spring cabbage and salad onions which are overwintered. These four species occur on vegetable holdings throughout the country, but in some areas *Polygonum persicaria* L. or *Solanum nigrum* L. assume importance while several other species, among them *Senecio vulgaris* L., *Capsella bursa-pastoris* (L.) Medic., *Veronica* spp., and *Matricaria* spp. are of frequent occurrence. It is noteworthy that summer annual grasses (e.g. *Setaria* spp.) and parasitic weeds, which are often important in warmer climates, do not constitute a problem in Britain.

Certain species may be especially serious in particular crops. *S. nigrum* and *Cirsium arvense* (L.) Scop., for example, are troublesome when they occur in peas grown for vining because the berries and capitula respectively are difficult to separate from the peas. In crops which occupy the land for several years, such as asparagus, perennial weeds become more important, *Agropyron repens* (L.) Beauv., *Convolvulus*

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arvensis L., and *Cirsium arvense* being the most common. These species may also be troublesome on land which is being taken over for market-gardening, but once a system of vegetable cropping has been established, they tend to disappear. In transplanted crops such as Brussels sprouts and cauliflowers, weeds can usually be adequately controlled by cultivation, and in row crops generally, tractor cultivation is a cheap and effective method for disposing of weeds between the rows. It is the weeds growing close to the crop plants in the rows which present the challenge to the herbicide research worker.

Chemical Control Methods

Before the 1939–45 war, it could be said that in vegetable crops 'cultivation methods must still be relied upon for weed eradication' [1]. This remained largely true during the immediate post-war years, for the chemicals DNC, MCPA, and 2,4-D, which by that time were being widely used on cereal crops, proved to be of little value to the vegetable grower. Nevertheless, those years saw the development of a few herbicides which could be used for selective weed control in certain vegetable crops and more recently others have been discovered. The advent of contact pre-emergence spraying has also extended the range of crops in which some measure of weed control can be attained by chemical means. The practical applications of these herbicides have been reviewed by various workers [2, 3, 4, 5] and in Table 1 the methods at present used commercially in Britain are summarized. Individual chemicals are considered in the following paragraphs, without attempting, however, to give detailed recommendations, which can be found elsewhere [6].

Sulphuric Acid

Experience with sulphuric acid for the control of annual dicotyledons in cereal crops indicated that the selectivity obtained was largely a result of morphological differences. The similarity in habit of growth between onions, leeks, and cereals suggested that these two vegetable crops might also be tolerant, and during the 1939–45 war, successful trials were carried out on both crops [7, 8, 9, 10]. It was found that in order to avoid crop damage, spraying should be delayed until the onion seedlings had straightened up, by which time the weeds were often well grown and difficult to kill. It was shown, however [11], that the first flush of weed seedlings could be destroyed by spraying sulphuric acid just before the onions emerged, while those appearing later could be killed with a second spray when the crop had reached the correct stage of growth. This technique of pre-emergence spraying followed by a post-emergence spray was rapidly adopted by growers and is still in use today. Sulphuric acid is relatively cheap, leaves no toxic residues in the soil, and kills most weeds in the seedling stage, *Poa annua* being a notable exception. Unfortunately, its corrosive properties are a serious disadvantage which tend to limit its use and render the development of alternative materials desirable.

TABLE 1. *Herbicides used Commercially on Vegetable Crops in Great Britain*

Herbicide	*Crop*	*Approximate rate of application*	*Stage of crop growth at which applied*
Selective post-emergence			
Sulphuric acid	Onions	5–10%, high volume	when onions have straightened up
	Leeks	5–10%, high volume	during the first month after planting out
Mineral oils	Carrots	40–80 gals./acre	from first true leaf to 'pencil thickness' of root
	Parsnips	40–60 gals./acre	after two true leaves
	Parsley	40–60 gals./acre	after two true leaves
Dinoseb (amine)	Peas	up to 3 lb./acre, high or medium volume	after first leaf has expanded
Sodium nitrate	Red beet	2½ cwt./acre + wetter, high volume	after two true leaves
MCPA (salt)	Established asparagus	up to 2 lb./acre, high volume	directed spray at base of mature bower
MCPB (salt)	Peas	up to 2 lb./acre, high or low volume	between three and six leaves. (Certain varieties only.)
Contact pre-emergence			
Sulphuric acid	Various	10%, with or without wetter, high volume	before crop has begun to emerge
Vaporizing oil	Various	40 gals./acre	
Pentachlorophenol (miscible oil formulations)	Various	3 lb./acre, medium volume	
Cresylic acids	Various	5 gals./acre, high or low volume	
Residual pre-emergence			
Monuron	Established asparagus	2 lb./acre, high volume	before spear emergence in spring

Mineral Oils

Following reports from the U.S.A. and Australia that certain light oil fractions could be used for the selective control of annual weeds in carrot crops, experimental work began in this country in 1945. This was mainly directed towards evaluation of the different types of oil then available, and correlation of observed differences in phytotoxicity with such characteristics as aromatic content and boiling-point range [12, 13]. In practice it was found that most tractor vaporizing oils were suitable,

but because of unpredictable variation it has always been recommended that the effect of a particular batch should first be observed on a small area of crop before spraying the whole field. There have been reports of taint in the crop as a result of using oil sprays, but with maincrop carrots the risk is negligible provided that spraying is carried out at an early stage of growth. Fractions of the white-spirit type are much less likely to cause taint, and proprietary brands standardized for herbicidal use have been available for some time. Their liability to excise duty, however, renders them too costly for field-scale application, and their use tends to be restricted to carrots grown for bunching, either outdoors or in frames. For maincrop carrots, the use of tractor vaporizing oils is now standard practice, and in some of the major carrot-growing areas more than 90 per cent. of the crops are so treated. These oils can also be used selectively in other umbelliferous crops, parsnips and parsley, but both are rather more susceptible than carrots. In general, however, the use of light mineral oils for weed control in these three crops is considered to be a satisfactory and economic practice.

Sodium Nitrate

It has long been known that beet can withstand higher concentrations of sodium salts than many other species and attempts have been made to utilize this difference in formulating weed-control measures. In 1953 the National Agricultural Advisory Service reported successful results with a spray containing 2½ cwt. of sodium nitrate together with 1 gallon of a proprietary wetting agent, applied at 100 gallons per acre [14], and similar results for sugar-beet were obtained at the Norfolk Agricultural Station [15]. Unfortunately, this method has proved rather unsatisfactory in practice. Sometimes good results have been achieved, whereas at other times even applying the spray at twice the rate has failed to give adequate weed control. Parker [16] records that in 1955 out of sixty-five commercial applications to sugar-beet, 20 per cent. were highly successful, 40 per cent. satisfactory, and 40 per cent. failures. Besides this unreliability, sodium nitrate does not control other Chenopodiaceae which are often present in beet crops, and is relatively expensive, although the fertilizer value can be set against the cost. For these reasons, it is not widely used at present for weed control in crops of beet.

Pentachlorophenol

Although the herbicidal properties of pentachlorophenol have been known for some time, it is only in the past few years that it has been used commercially for weed control in vegetable crops. During 1951 and 1952 experiments were carried out in which pentachlorophenol was used as a fortifying agent in sprays of vaporizing oil or emulsions of vaporizing oil in water [17, 18]. Commercial formulations later became available consisting of concentrates in non-persistent oil which merely required dilution with water before use, and these formulations are now employed for pre-emergence weed control in a variety of crops. Although primarily designed for use on crops in which germination is slow, the method is applicable also to those crops which germinate rapidly if the 'stale

seed-bed' technique is used [19, 20, 21]. Pentachlorophenol appears to be perfectly safe for use on large-seeded crops, but there have been instances of damage to onions and beet, usually associated with a light soil and heavy rain after spraying. Despite the limitations of the contact pre-emergence method which have been discussed elsewhere [18], it would appear that many growers find pentachlorophenol formulations to be valuable.

Dinoseb

Following the discovery of the herbicidal properties of dinoseb (2, 4-dinitro-6-secondary butylphenol, formerly known as DNBP) in the U.S.A., it was found that solutions of the ammonium salt would selectively control many annual weeds in pea crops. Experimental work in Britain confirmed this, and in a short time spraying with dinoseb (ammonium) became a commercial practice. Although very satisfactory on peas grown for drying, it was found that many of the varieties grown for vining or picking for market were more susceptible, so that the ammonium salt has never been generally recommended for these varieties. More recently, formulations based on alkanolamine salts have become available and have been shown to possess several important advantages over the older ammonium salt [22, 23]. The selectivity is greater than that of the ammonium salt, permitting application when the peas are at an early stage of growth and the weeds are most susceptible, and application can be made at medium as well as high volume. Dinoseb (amine) is thus an effective herbicide for the control of most annual weeds in crops of market-garden peas and is being increasingly used. It is poisonous, however, and its handling and application are governed by the regulations of the Agriculture (Poisonous Substances) Act, 1952, so that unless a grower has suitable equipment and can observe all the precautions required by law, it is necessary to employ a contractor.

MCPA

Vegetable crops on the whole are very susceptible to MCPA (2-methyl-4-chlorophenoxyacetic acid), even at rates lower than those necessary for weed control. As the sodium or potassium salt, however, it can be used to control perennial weeds in established beds of asparagus [4]. It is applied as a directed spray to the weed foliage, avoiding the asparagus as much as possible, and if delayed until the weeds are well grown, can effect substantial reductions in the numbers of shoots of *Convolvulus arvensis* and *Cirsium arvense* appearing in the following year. It has also been used as a pre-emergence spray to control seedling weeds in established asparagus.

MCPB

Investigations by Wain and his co-workers resulted in the development of a series of substituted phenoxybutyric acids of considerable practical importance [24, 25]. These compounds are not actively phytocidal but are oxidized in the plant to the corresponding phenoxyacetic acids which are active. Their selectivity stems from the fact

that plant species differ in the extent to which this conversion takes place. In the initial tests, peas, carrots, parsnips, and celery were found to be the most tolerant of the vegetable crops. As a result of further work, MCPB (4-(2-methyl-4-chlorophenoxy) butyric acid) was selected for development and became commercially available as the sodium salt in 1955 [26]. Field tests confirmed the comparative tolerance of peas but showed that with carrots and parsnips application of MCPB led to root abnormalities which affected the marketability of the produce [26, 27]. Later work with peas has been concerned with differences in susceptibility between varieties and although the evidence for some of them is conflicting, there is general agreement that Onward and other important varieties are tolerant while a few, including Kelvedon Wonder, are more susceptible and should not be sprayed [28, 29, 30]. Experience with MCPB has shown that *Urtica urens*, *Chenopodium album*, and other serious weeds of pea crops can be killed, but that others, among them *Stellaria media*, are tolerant. MCPB is useful therefore when susceptible weeds occur in a tolerant variety of peas; otherwise dinoseb (amine) is to be preferred. MCPB is especially valuable, however, if *Cirsium arvense* is prevalent, since good control of this species can be obtained. Field experiments have confirmed the relative tolerance of celery to MCPB, but in some instances deleterious effects on the crop have been observed and at present its use in celery is still in the experimental stage.

Monuron

Initial reports from the U.S.A. indicated that in addition to its primary use as a soil sterilant, monuron (3-(p-chlorophenyl)-1, 1-dimethylurea, formerly known as CMU) had also proved promising as a residual pre-emergence herbicide in several vegetable crops. The first trials in Britain also suggested that certain crops were sufficiently tolerant for this method to be used [31], but later work showed that the degree of selectivity was not great enough to allow for variations in the type of soil and in the amount of rainfall following spraying [32, 33, 34]. Other reports from the U.S.A., however, indicated that the perennial crop, asparagus, would tolerate an application of 2 lb. per acre which was often sufficient to keep the beds free from annual weeds for the whole season. The effectiveness of this treatment has been confirmed in Britain [35] and it has now begun to be used commercially. There is also some evidence [35] that monuron can be safely used as a pre-emergence spray for asparagus seed-beds, where weeds can be serious owing to the very slow germination of the crop.

Other Herbicides

In addition to the above herbicides, others have been used on a small scale but for various reasons have not been generally accepted by growers. *Calcium cyanamide* in either granular or dust form has been used for many years on asparagus and onions in some areas, but has tended to be displaced by the more recently developed chemicals already mentioned. *Potassium* and *sodium cyanates* have also been used as pre- and post-emergence sprays for weed control in onions, but although

satisfactory under some conditions, they have often failed to give adequate control and have therefore not been widely adopted. Proprietary formulations of *cresylic acids*, on the other hand, after being used on a small scale for a number of years, are now gaining favour and in 1957 were used in pre-emergence application on a wide range of crops with considerable success.

Discussion

Examination of Table 1 will show that despite recent advances in the herbicide field, selective methods of chemical weed control are available for use in only a few vegetable crops. Moreover, several of the herbicides in commercial use have some serious disadvantages; sulphuric acid is corrosive, dinoseb is poisonous, and sodium nitrate is unreliable. It must be realized, however, that vegetable crops pose difficult problems in that they are often morphologically similar or botanically related to the weeds which occur in them. Nevertheless, further progress can be expected and some ways in which this may be achieved are discussed below.

Development of New Post-emergence Selective Sprays

Of the selective herbicides at present in use for vegetable crops, the mineral oils and growth-regulating substances are physiologically selective, sulphuric acid and dinoseb depend largely on differential retention whilst the basis for the selectivity of sodium nitrate has not yet been fully explained. It seems probable that the continual synthesis of new groups of chemicals by manufacturing concerns will ultimately lead to the production of herbicides selective in other crops. Fundamental biochemical investigations may also have important practical results, as in the case of MCPB, and there is still a place for new contact herbicides without the undesirable properties of existing ones. A chemical of this type, *sodium monochloroacetate*, has recently been described as a herbicide for certain weeds in cereals [36] and is being investigated as a possible treatment for weeds in onions and in brassica crops. There may also be possibilities in chemicals such as *sodium 2, 4-dichlorophenoxyethyl sulphate* and its allies which are inactive until partial breakdown in the soil has occurred.

Development of New Pre-emergence Herbicides

In recent years the contact pre-emergence method has become widely recognized and practised by growers. This technique requires critical timing and is unsatisfactory if an appreciable proportion of the weed seedlings appear after the crop has emerged. Although undoubtedly valuable, further development would seem to be limited because of the disadvantages inherent in the method. Residual pre-emergence techniques, on the other hand, offer great possibilities if suitable chemicals can be found. Ideally, the herbicide would be sprayed on the soil immediately after sowing, would kill weed seedlings germinating during most of the life of the crop, and would then disappear. In order to be completely safe, it would be necessary for the crop to be physiologically

resistant to the particular chemical employed. Although at first sight such a specification seems difficult of attainment, it must be remembered that with most herbicides which have been investigated there are certain weed species which can tolerate application rates sufficiently high to kill the remainder. *Fumaria officinalis* agg., for example, resists monuron at 2 lb. per acre, while *Senecio vulgaris* is unaffected by rates of CIPC (isopropyl N-(3-chlorophenyl) carbamate) which kill most other species. The reasons for this resistance in particular species are not known, but it seems probable that sooner or later a chemical will be discovered to which one of the important vegetable crops will be resistant. As already mentioned, experiments with monuron applied to asparagus seed-beds suggest that in this instance there is some degree of physiological tolerance.

Even when such resistance does not exist to any marked extent it may still be possible to use residual pre-emergence herbicides if the crop seeds are protected by the layer of soil above them. Since the success of a treatment would be governed by the nature of the soil and the amount of rainfall as well as the physical and chemical properties of the herbicide, however, it would be difficult to make general recommendations. Nevertheless, when the crop has large seeds which are sown deeply, a residual pre-emergence treatment may be feasible. Dinoseb (amine), for example, at rates higher than those used in post-emergence work, has given encouraging results in pre-emergence applications on various kinds of beans.

Use of Mixtures of Herbicides

The weeds present in a vegetable crop usually comprise several species with varying degrees of susceptibility to any one herbicide and to increase the rate of application to a level necessary to kill all of them may not be possible because of the risk of crop damage. This might be overcome by the use of a mixture of relatively low rates of two independently acting herbicides which are complementary as regards species killed. This approach so far has only been followed to a very limited extent in Britain, but it would seem to be a promising one, particularly with residual pre-emergence herbicides. It would also hinder the building up of high populations of resistant species and the development of resistant strains [37].

Use of other Application Techniques

An obvious way of killing weeds without harming a crop is to direct the spray so as to wet the weed foliage but not that of the crop, as mentioned previously for perennial weed control in asparagus. The habit of growth in most vegetable crops precludes this type of application, but it remains a possibility for certain of them. If it is desired to kill germinating weeds in a transplanted crop, a kind of physical selectivity could be achieved by the use of granular formulations. These have met with some success in the U.S.A. and would seem worth while

investigating in this country. Another technique which may prove suitable for some vegetable crops is that of pre-planting application in which a herbicide is mixed with the soil some time before drilling the crop. Successful control of *Avena fatua* L. in pea crops has been attained using sodium trichloroacetate in this manner [38, 39]. A somewhat similar principle is involved in the use of soil fumigant chemicals applied in drench form, which could be useful for small areas such as brassica seed-beds and Dutch-light frames. In an ingenious adaptation of the pre-emergence method which has been recently described [40], the crop seeds are protected from the chemical by a layer of adsorbent sprayed into the drill, and this technique could be useful in vegetable production.

Conclusions

It would seem that the ideal herbicide treatment for a vegetable crop must either be a highly selective post-emergence spray which can be used at an early stage of crop growth before weed competition begins, or a safe and reliable residual pre-emergence herbicide. At present, for the majority of crops, the herbicides available fall far short of this ideal, so that methods such as that of contact pre-emergence, which by-pass the need for selectivity, are likely to remain important until new selective chemicals are discovered.

The demand for chemical methods of weed control is certain to increase. Hand-weeding, once a routine measure, is now obsolescent and growers are looking towards herbicides as one of the main ways of increasing productivity and decreasing costs. Existing chemical methods of weed control usually cost a minimum of £2 per acre for materials alone, but this represents only a fraction of the cost of inter-row cultivation followed by hand work, even if the labour is available, and many growers would be prepared to pay considerably more provided that spraying could be relied upon to be effective. In considering weed-control costs it should be remembered that in addition to removing the direct effects of weed competition, good weed control reduces the cost of other operations such as thinning and harvesting, improves quality, and by preventing weed-seed production facilitates operations in subsequent years.

Much of the research on herbicides in Britain to date has been concerned with cereals, grassland, and other crops grown on a farm scale. More attention is now being paid to the problems of the vegetable grower, however, and it is to be expected that this work will yield practical results. In order to apply them to the best advantage, much more ecological information is required about the weeds themselves, their competitive relationships with vegetable crops and the effect of cultural practices on their prevalence. Research on these aspects is proceeding at the National Vegetable Research Station and at other research institutions and universities, and in conjunction with improved herbicides could make an important contribution to the production of vegetable crops in Britain.

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Since this article was written, residual herbicide formulations comprising mixtures of CIPC and fenuron (3-(phenyl)-1, 1-dimethylurea) have become available and are recommended by the manufacturers as pre-planting, pre-emergence, or post-emergence sprays for a variety of vegetable crops. These formluations have been used commercially during 1958, but as yet there is insufficient information with which to assess their effectiveness under different soil and climatic conditions.

LAND-USE IN THE CARIBBEAN: ADVANCES DURING THE LAST TWENTY-FIVE YEARS TOWARDS A SCIENTIFIC POLICY*

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'AND some fell upon a rock; and as soon as it was sprung up, it withered away, because it lacked moisture . . . and other fell on good ground, and sprung up, and bore fruit an hundredfold. . . .' (Luke, viii. 8, 6.)

The varied fertility of different land was clearly appreciated in Biblical times. From then till now has been a long time for an understanding of this to be used as a basis for sound agricultural practices. In this evolutionary period there have been three distinct phases of development. In the first phase there was a growing awareness of the need for correct land-use. This awareness has been partially the outcome of catastrophes on a scale large enough to affect even the destinies of nations. Anthropological research and modern knowledge of soils have attributed, for instance, the downfall of Babylon to the salinization of impermeable arid clays. According to one theorist, the Maya civilization of Central America perished against the weight of a relentless environment through excessive growth of weeds in their fertile subtropical soils. The passing of power from Greece to Rome is considered by some to be partly attributable to goat-induced erosion. In more recent times dust-bowl conditions in North America have resulted from over-exploitation of a humic top-soil.

Human disasters of these proportions ushered in the second phase in the development of man's need for correct land-use. This second phase brings us to the present day when awareness has been supplemented by a greater understanding of the principles involved. Fundamental soil studies, applied developments therefrom, soil surveys and classification, and standardization of methods are providing a rapidly shortening route leading directly to practical application.

Mankind may then be considered at the threshold of the third phase in the evolution of correct land-use practices. This phase involves correction of past mistakes and the progressive replenishment of losses over what may have been, in cases of extreme misuse, a very long time. Progress in this phase is seriously hindered by the inherent conservatism of man. This is a failing of all ranks of society, not the least offenders coming from the illiterate and ignorant peasants who, through the misfortune of their birth, are the foundlings of social structures out of harmony with environment. The almost insuperable social curse of land-fragmentation by inheritance frequently ravages the social structure

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of tropical countries—countries which it must be appreciated receive much of their rainfall at high storm intensities. Land-fragmentation by inheritance and torrential tropical rainstorms are two factors which together are irreconcilable in the establishment of sound land-use policy. The third phase in man's development of a system of good land management is therefore essentially instructional and involves the promotion of a viewpoint, possibly in the face of persistent opposition, indifference, and unbelief. Essentially then a very slow process, requiring rising educational standards keeping pace with instruction, these tasks are fittingly entrusted to organizations of the international calibre of FAO or UNESCO or of regional emphasis.

It is appropriate, therefore, at this stage to review what progress has been made in this direction in the Caribbean region, that region which is the specific responsibility of the Regional Research Centre at the Imperial College of Tropical Agriculture, Trinidad. In the early days of Caribbean development abuse of natural soil resources arose from prodigal demands on the fertility of the humic layer of tropical forest soils. No single agricultural myth has been more shrouded in mystic qualities than this ready belief in the unfailing fertility of tropical soils. In those early halcyon days soil degradation was rapid; plantation agriculture combined with heavy cropping, the disturbance of forest conditions, and the active depletion and destruction of the humic soil layer induced catastrophic erosion. With the exhaustion of the transient humic reserves of the top-soil, there was exposed a mineral soil profile which had already undergone intense tropical weathering and which was so depleted of those factors essential for plant growth as to make it a very inferior growth medium. This subsoil previously had been spared heavy demands on its own restricted resources by the protecting upper humic layer with its nutrient store accumulated during the growth cycle of its forest cover. The degree of ecological imbalance induced by these profound changes helped slowly and inevitably to emphasize the regional need for a programme of soil restoration.

At this stage the second phase in the development of sound land-use in the Caribbean may be considered as having begun. It coincided approximately with the early days of the current era of scientific agriculture when there was a growing realization that many sociological problems of the world were amenable to a scientific solution. Caribbean soil problems, in particular, became the absorbing interest of Hardy, who for thirty years, in close association with his colleague Rodrigues, studied the fundamental aspects of soil relationships in the Caribbean. They elaborated a provisional soil classification for volcanic islands and developed a strongly flavoured ecological approach in their studies, regarding 'the soil, the plant, and the atmosphere as component parts of a single system'.

These fundamental studies were directed into practical channels by the provision of funds in 1948, by the Government of the United Kingdom, for a Regional Soil Survey Scheme. The staff of the scheme used the fundamental researches of Hardy and Rodrigues as a skeleton on which to base their soil studies. In so far as this work was essentially

transitional towards the final aim of its application in agricultural practice, the urgent need was for a system simple and free of academic details and in a form that might be readily appreciated and understood by the farmer. A land-capability method has therefore been devised, modelled closely on a similar method practised in the U.S.A. and adapted specifically to the environmental conditions in the Caribbean islands. In this method soils are differentiated in the field according to the morphological characteristics of their profiles, the slopes on which they occur, and the degree of erosion which they have suffered, assessed according to an empirical, numerical scale. A soil map then pictorially records these facts for all land within the area surveyed. Profiles are judged strictly from the needs of the growing plant and special emphasis is given to such qualities as nutrient reserves, erosion risk, drainage, shallowness, rockiness, and droughtiness, and their relationship to the health of the roots. Several groupings of land-capability have been established in consequence. Superimposed on the detailed soil survey data, these groupings produce a systematic record of the survey which can be arranged in a form for easy reference and direct translation into farming practice.

The problem now becomes one of dissemination of information. This has been handled realistically in Jamaica by the formation of a group of land-capability officers whose function is to carry the background knowledge of the soil and land-capability survey literally into the field, to carry out subsidiary surveys on a more intensive scale, often on a unit-farm basis, and to offer guidance and advice based on knowledge gathered during the course of the soil survey. To facilitate this phase of the work officers are provided with technical guide sheets, each sheet prepared specifically for each soil unit demarcated under the dominant environmental conditions in which that soil unit is found. The procedure followed, therefore, by a land-capability officer is to conduct a rapid soil survey by auger on a field-to-field basis; to recognize the individual soil units by familiarity with the regional soil survey findings; to construct a large-scale soil map for the owner's guidance; and to make recommendations for each soil unit recognized, by reference to the technical guide sheets already compiled. Much care and thought go into the preparation of these technical guide sheets which demands from the compiler an intimate knowledge of soil conditions, soil distinctions, environmental factors, and local agricultural practices and crops. The finished sheet is never regarded as final, but is subject to continuous revision and improvement as further knowledge becomes available of a particular soil type and as economic and general market conditions dictate. The sheet contains a fertilizer recommendation, necessarily a variable factor since fertilizer requirements change with continued use of fertilizers. The psychology, however, of disseminating information to peasant cultivators is more adroitly handled by presenting them with a fixed notion, such as this, which they may quickly accept rather than by expecting them to grasp readily the greater complexity of variable fertilizer need.

The adoption of this system in Jamaica has had very encouraging

results. Metson, in his *Introduction to Methods of Chemical Analysis of Soil Samples*, claims that 'the fundamental soil unit, from the viewpoint of the farmer and the agriculturalist, is the soil type, and soil surveys and soil science in general may be said to have "arrived" when soil type names are in common use by the farming community'. It is gratifying to those engaged in soil work in the Caribbean to know that the close contact between the soil-survey organization and the farming community in Jamaica has already evoked the use by the farmers of the code numbers used by the surveyors for the different soils in the original survey work. The choice of number rather than name has arisen from the delay between the field work and the published report; although this delay is associated with the complexity of compiling and producing complicated maps it is detrimental to the ready blossoming of the survey if too long a period occurs between the field work when the surveyors move among the people, and the appearance of the printed report.

The relative success of these operations in Jamaica has provided an impetus for similar procedures to be initiated in the island of Grenada. 'It is an ill wind that blows no one any good.' The arrival of hurricane 'Janet' in Grenada in 1955 certainly facilitated soil-survey operations. Heavily wooded terrain, with restricted visibility over broken relief, which otherwise would have hampered the speed of operations, became relatively favourable for soil-survey work. As a result a soil-survey map has now been compiled. Technical guide sheets will be issued for the main soil units and slope categories after discussion with the experienced agriculturalists and following a close study of the agricultural conditions in the island. A similar survey in St. Vincent has been completed and awaits the opportunity of carrying the survey into the next stage of land-capability appraisal. St. Vincent in addition to analyses of major and minor elements in its soils has further received a preliminary study of its trace-element status. This was undertaken since the well-leached soils of higher altitudes of the volcanic islands in the Caribbean were known to be incapable of carrying stock to healthy maturity. The limiting factor to growth may prove to be a mineral deficiency. Although the experiments have been conducted on soil samples collected in St. Vincent the findings may well have regional significance for the volcanic arc of Caribbean islands.

The emphasis in all this work has been on restoration of soils damaged by previous misuse. In British Guiana, however, work conducted by the Soil Research and Survey Department of the Regional Research Centre has been directed towards the possible development of an inherently infertile area which might be brought into productivity by the use of modern agricultural scientific techniques. Two thousand square miles of grassland savannah were surveyed in this project in an area currently under a ranching system of land-use and with a carrying capacity of one beast to 75 acres. Following a survey of soils and environmental conditions, recommendations have been made for certain scientific experiments to be conducted to test the possibility of improving the area. In these recommendations rectification of trace-element deficiencies has been prominent, since the area, which suffers extremes of inundation and

drought, is generally composed of highly weathered strongly leached soils.

In our Soil and Land-Use Survey report on St. Catherine Parish, Jamaica (recently published), we have emphasized that, 'the most effective way of portraying the value of beneficial treatments and methods is to show the farmer that these techniques will increase actual income. Too often today the reaction of the farmer to a method proved by the Department of Agriculture is that "Government can make it work, for Government does not count the cost". This understandable reaction could be changed by proof of actual economic gain, especially if the experiment is carried out on the crop and land of a private farmer and not on an agricultural station.' It is particularly pleasing, therefore, to read in editorial comment in *World Crops*, November 1957, that a discussion on Dr. H. L. Richardson's paper on fertilizers in the Far East (1957) (Proc. No. 41 Fertilizer Society) included a statement by Mr. H. J. Page to the effect that the surest method of developing 'fertilizer-consciousness' and fertilizer-use among peasants and small-acreage farmers was to carry out fertilizer experiments on the spot on the actual soils of the farmers. Results obtained at official experiment stations, Mr. Page claimed, 'were treated with scepticism and the view was often taken that the Research Station had unlimited resources and could therefore afford to experiment to an extent that ordinary cultivators could not. In short, "remote" science fails to pay off. The straightforward demonstration plot, though it risks errors of misinterpretation by lack of replication, is neither remote nor complex. Research plots with various complexities have a somewhat "highbrow" background. It is certainly difficult to use this type of research-evidence for educational purposes without a considerable degree of popularization.'

The work of the Soils Department of the Regional Research Centre at the Imperial College of Tropical Agriculture is therefore approaching the third phase in establishing sound land-use methods and soil-management practices within the Caribbean—a phase in which the main obstacle to progress is the difficulty of convincing the people of the usefulness of the methods being devised and made available for them. The main tragedy confronting us in our efforts is the possible relegation of our soil maps to the office wall. To pursue our studies to their logical fulness we must now either divert our surveyors from the task of mapping (before the job is complete) or seek additional qualified men specifically for the task of developing 'fertilizer-consciousness' together with a consciousness of good land-use. It is perhaps very propitious that the birth-pangs of this need are being experienced at a time when the West Indian Nation is being formed. It will be regrettable if the political issues of the moment eclipse the equally vital socio-agricultural problem of sound land-use within the Federation.

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A CLASSIFICATION OF ZEBU CATTLE TYPES IN TESO DISTRICT, EASTERN PROVINCE, UGANDA

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WITH PLATES 8 TO 10

Summary

By considering variations in conformation and other physical characteristics occurring in the cattle population of Teso District, Uganda, four main cattle types, namely, the Small Shorthorn Zebu, the Serere, the Kyoga, and the Usuku are differentiated. The characteristics of the four types are described. The geographical situation of the types and the tribal history of the Iteso are considered to support the classification and to relate the type to the Karamojong, Nganda, and Ankole type of cattle which occur in adjacent districts.

REFERENCES to cattle types occurring in Uganda, and in Teso District in particular, are extremely limited in previous literature. Faulkner and Brown [1] in a report on African cattle refer to two types—'the small shorthorn Zebu, which forms by far the largest proportion of the cattle population in Uganda and which, as in Kenya, appears to be commonly found in the higher rainfall areas such as Teso and Lango while the large shorthorn Zebu, which is found in Karamoja, is of the Boran type similar to that found in the drier areas of Kenya'. Epstein [2] makes a similar observation but prefers the term 'chest-humped Zebu' to 'shorthorned Zebu'.

Mason [3] recognizes two main types, namely the 'East African Shorthorned Zebu', in which he includes the Karamoja and Bukedi type, and the 'Nganda' in which he includes the Kyoga type.

In Teso, due to indiscriminate breeding and constant cattle movement, types existing originally must have, to a varying degree, become absorbed and altered so that type differentiation can in no way be clear cut. In the present paper various factors have been considered in differentiating these types: (i) Size and conformation, (ii) Colour, (iii) Horns, (iv) Humps, (v) Dewlap and sheath, (vi) Ears, (vii) Origin. All characters are compared with those of the predominant small shorthorn Zebu type.

Size and Conformation

Size may be influenced by type or breed, climate, nutrition, and management. Fortunately there exists at the Serere Experimental Farm a herd of small shorthorn Zebu type kept under conditions of optimum nutrition and management so that any group of animals in the district which exhibits consistently a larger size under the same climatic conditions may be tentatively taken as being of a different type.

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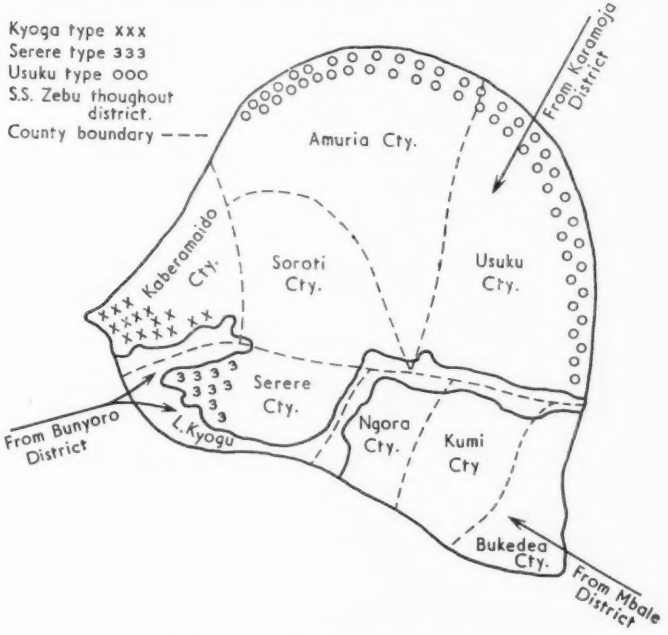
Animals of a larger size of different conformation do, in fact, occur as follows:

(i) *Kyoga type*: Animals of this type occur in the southern tip of Kaberamaido county (which is an extension of Kyoga peninsula in Lango, where the type also occurs) and the animals are decidedly bigger where the standard of management is reasonable.

(ii) *Karamojong type*: This type is to be found in the north of Usuku and Amuria counties along the Karamoja border.

(iii) *Serere type*: This type occurs along the lake shore of Serere county and is larger than the small shorthorn Zebu type.

(iv) *Usuku type*: This type occurs along the Teso–Karamoja border. (See Map 1, showing distribution of types.)



MAP 1. Distribution of cattle types.

The climatic conditions in Teso are fairly uniform, apart from the northern belt along the Karamoja border, so that this factor is unlikely to be of significance except as affecting animals of previous origin, and the Karamojong type.

Little is known concerning the nutritive value of pastures in Teso, but it is doubtful if there is any significant variation between areas sufficiently great to affect the size of the cattle. Nutrition, however, may be considered in that the availability of grazing does vary according to the stocking density. Nutrition during the early life of calves also

varies according to the standard of management. The former is evidenced by the fact that there is an increase in size of the cattle (particularly in the more heavily stocked counties of Bukedea, Kumi, Ngora, and Soroti), the further the locality is from the main road, i.e. as the stock population thins out. The latter is even more strikingly demonstrated by the enormous variation in size of cattle in the same area depending on the standard of management. The eventual size is thus greatly influenced by calf management. In comparison with the small shorthorn Zebu, the Karamojong type is only slightly taller but is longer in the leg, and has a comparatively larger head. The Kyoga is taller and in contrast to the Karamojong type is deeper in the chest and shorter in the leg. The head is approximately the same as or smaller in size than the small shorthorn Zebu and the width of the skull between the eyes appears greater. Comparative measurements of twenty bullocks of the small shorthorn Zebu, Karamojong, and Kyoga types failed to show significant differences [4].

Colour

The predominant colours are black, black and white, brown, brown and white, red roan, grey roan; white and cream also occur but tend to be found only in certain areas. Brindle is an uncommon colour, which is surprising as it is much favoured by the Iteso.

Black and brown whole colours are more common among the Kyoga type of cattle and, to a lesser extent, in the cattle in the southern part of Serere county.

Red and grey roans tend to be commoner in the north of Amuria and Usuku counties along the Karamoja border and this can be attributed to the fact that these colours are very common in Karamojong cattle. Partial sex linkage of pigmentation in silver-grey coat colour was not observed in any of the types [2].

Two distinctive colour patterns have been recognized:

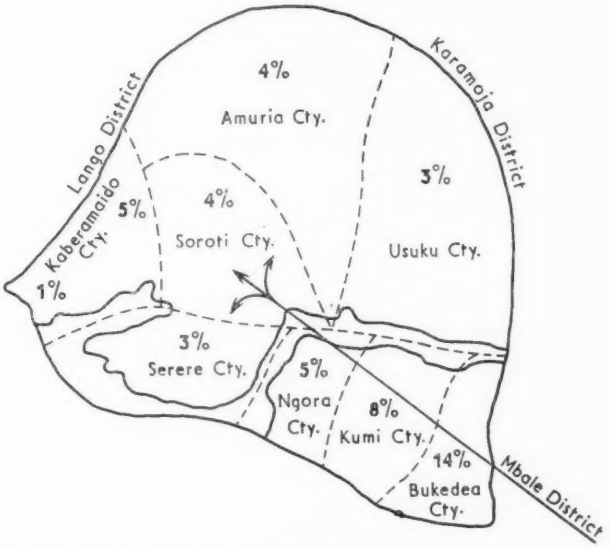
(*a*) Black sides with white face and stripe along the back, and white belly (Fig. 1, Plate 8). A variation also occurs, black being replaced by brown, but this is rare. This marking, which will be referred to as 'Dalmatian' in the following text, is fairly common throughout the district but is rare in Karamojong and Nyoga types. Counts of the incidence of this pattern were done and are of interest in that they appear to indicate that the origin has been through Bukedea county from Mbale District.

'Dalmatian' Marking Distribution

County	*% Incidence*	*County*	*% Incidence*
Bukedea . . .	14	E. Kaberamaido .	5
Kumi . . .	8	SE. Kaberamaido .	1
Ngora . . .	5	Amuria . . .	4
Serere . . .	3	Usuku . . .	3
Soroti . . .	4		

The above is illustrated in Map 2.

Oliver [5] and Joshi and Phillips [6] describe this marking as being typical of the 'Dhanni' breed of cattle found in the Punjab and North-West Frontier Province of India. Descriptions and photographs given by the above authors show that this breed in some way resembles the small shorthorn Zebu type as it occurs in Teso District. This marking



MAP 2. Percentage distribution of 'Dalmatian' pattern in Teso District, showing apparent origin.

is said to be fairly common also in cattle in Kenya and Tanganyika and this fact, coupled with the view expressed by Curson and Thornton [7], that shorthorn Zebu cattle in East Africa were introduced by Arab and Indian traders during the 'Third bovine invasion of Africa', may well be of significance in determining the origins of East African cattle.

(*b*) The body colour is a very dark brown, the legs, hump, and shoulders being dark with a fawn-coloured stripe about 2 in. wide extending from the hump along the back to the tail. This light fawn extends between the horns, inside and on the tip of the ears, and around the muzzle. This colour pattern is prevalent in Kyoga type but occurs throughout the District. It does not appear to be a marking found in Karamojong cattle. This marking is referred to in the text as 'Eland' type pattern (Fig. 2, Plate 8).

(*c*) A third colour pattern, which can be described as a variation of the 'Eland' marking, occurs in grey roan animals, where the body colouring is grey roan and the extremities are light grey to silver in colour. This marking is fairly common among Kyoga types and Karamojong cattle, but rare in the small shorthorn Zebu.

Horns

The prevalent type of horn is of medium length, round in cross-section, rather resembling that of the Ayrshire breed in type and direction of growth (Length 9 in., circumference at base 7 in.) (Fig. 3, Plate 8). Bullock horns are slightly larger and bulls' horns slightly shorter. This is the predominant type of horn in the small shorthorn Zebu in Teso. In the Kyoga type the above type of horn occurs but also fairly common is a shorter thicker type which slopes outwards and slightly backwards. This is typical of Kyoga type males (Fig. 4, Plate 8). In Karamojong cattle the horns appear to be generally longer while many from Pian county (Karamoja District) show short backward-sloping horns as described above as typical of Kyoga. The following variations have been noted:

(*a*) *Long horns*: this type of horn is narrow (circumference 6 in. at base) and long (length 18 in.) and tends to grow with very little upward curve. It is rare, and is seen mostly in cattle with a small hump, as occur around the lake shore in Serere county (Fig. 5, Plate 8).

(*b*) *Necked horns*: this type does not occur in Teso but has been seen in Karamojong cattle which came from Dodoth county (length 20 in.). These horns narrow just before entering the skull. Circumference at base 9 in., circumference 1 in. from base 12 in. (Fig. 6, Plate 8).

Polling. Polling is fairly common throughout the District, and varies from 0·5 to 3 per cent. except in south-west Serere county where it has an incidence of 10 to 17 per cent. and is more commonly found in the small-humped animals of this area. Although polling does occur in Kyoga cattle, it is not common and this applies equally to Karamojong cattle. Polled cows appear to be more prevalent than polled bulls and bullocks. A random count on 300 cattle in Serere county, of which 12 per cent. were polled, showed a ratio of four female polled to every male. This may be due to sales of male stock, but this is doubtful.

Loose horns. This is fairly common but not so common as polled animals. The incidence in areas and types is the same as for polled animals and so far this phenomenon has seldom been seen in a male animal (Fig. 7, Plate 9). Mornet [8] describes a similar condition in French West African cattle although he found loose horns to be more common than polling.

Horn atrophy. Although this is not strictly within the scope of this paper, it may be of interest as it is not uncommon in Teso cattle. This causes the horn to be thinner with a rough surface which appears scaly, rather like a tree bark (Fig. 8, Plate 9). The hooves appear normal and the cause is not known. Mornet [8] described a similar condition in Chad cattle.

Humps

The size and shape of humps in Teso Zebus vary considerably. The hump in bulls is larger than in bullocks and that in bullocks larger than that in cows, as would be expected. The following remarks refer solely to bullock humps. The hump may be described as thoracic in position,

extending from the first to the fifth thoracic vertebral spines and occasionally extending to the last cervical spine and the sixth thoracic spine. It consists of muscle, very little fibrous tissue, and varying amounts of fat which is present between the muscle and the skin, and between the muscle and the vertebral spines. Little fat is found between the muscle fibres. This closely approximates to the description of the East African Shorthorned Zebu hump given by Milne [9]. The size of the hump greatly influences the external shape and three types of hump may be recognized:

(i) A small triangular-shaped hump. This type of hump may be so small as to be almost non-existent and is most commonly found in the lake shore cattle in Serere county (Fig. 9 (i)).

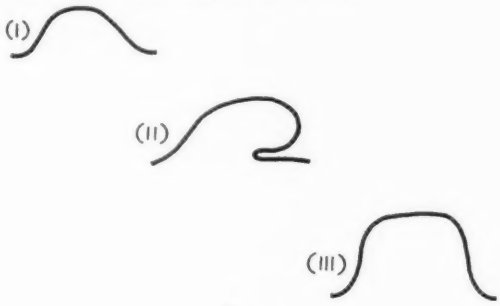


FIG. 9

(ii) A rounded hump. This is by far the commonest type. In Kyoga type cattle, it is not very large while in the small shorthorn Zebu it is slightly larger (Fig. 9 (ii)).

(iii) An upright dome-shaped hump. This occurs in cattle in north Usuku county near the Karamojong border and is also seen in the southern counties of Kumi and Bukedea (Fig. 9 (iii)).

Dewlap and Sheath

There is considerable variation in the dewlap and sheath in Teso cattle. The Kyoga type has a very well-developed dewlap and pendulous sheath in the bull and bullock, while in the females there is a small umbilical flap. In the Karamojong type the dewlap and sheath are similar to the Kyoga type although the sheath is not normally as pendulous. The dewlap in the small shorthorn Zebu type is not as extensive as in the above types while the sheath is not pendulous and the umbilical flap not normally present in females. The dewlap and sheath of the Serere and Usuku type are intermediate between the Karamojong and small shorthorn Zebu types.

Ears

The shape and size of the ear is fairly uniform in all types. The Kyoga and Karamojong types, however, frequently exhibit ears which are slightly pendulous.

Origin

In order to consider adequately the different cattle types in Teso District, it is necessary to study the origins of the Iteso tribe and this may be done by giving a short account of the history of the Iteso. (J. C. D. Lawrance, private communication, 1953.)

It is suggested that the Iteso originally came by way of Abyssinia and Karamoja. There are records of bushmen having inhabited the district prior to the arrival of the Iteso but it is thought that the area was uninhabited when they arrived. The 'first migration' of the Iteso began some 250 years ago from Karamoja into Usuku county. The 'second migration', which occurred some 150 years ago, took the Iteso from Usuku county to the other parts of the District, which brought them into contact with other tribes inhabiting Lango and Mbale Districts. It can be assumed, therefore, that the cattle in Teso District from A.D. 1700 to 1800 were of Karamojong origin while from 1800 onwards there would be a certain influx of other types from Lango and Mbale Districts. There is some doubt as to the origin of the Kuman tribe who are now found in Kaberamaido county but it is generally accepted that they have the same origins as the Iteso and probably separated only at the time of the second migration. Around the year 1895 Kaberaga, ruler of Bunyoro, took refuge in Kyoga peninsula. This king, who raided throughout Uganda prior to being driven out to Lango, collected many cattle during these raids and is said to have taken cattle with him when he fled to the Kyoga peninsula. This is quoted by the local people, who say that their cattle came from Bunyoro, as the origin of Kyoga cattle. Another legend states that the Kyoga cattle came from Karamoja District within the last 150 years, brought by a person named Olemmo. There is also a legend told in Serere county that the cattle type found along the lake shore there were brought from Bunyoro District around fifty years ago and this is partially supported by the fact that a great deal of trading between Bunyoro and this part of Teso occurred at this time.

Main Types of Cattle

Four main cattle types may thus be described:

Small Shorthorn Zebu (synonyms: Bukedi Zebu; Nkedi Zebu; Lango Zebu; East African humped Zebu; East African Zebu) (Figs. 10, 11, 12, Plate 9)

This is by far the predominant type in the District, amounting to over 90 per cent. of the total cattle population. The average wither height of a mature cow is between 39 and 42 in. and they rarely exceed 44 in. Bulls average between 40 and 43 in. and rarely exceed 46 in. Bullocks average between 43 and 48 in. and rarely exceed 50 in. The chest depth is little more than 50 per cent. of the wither height and the general appearance is that of a small dual-purpose type animal. In common with the other three types the hindquarters are relatively undeveloped compared with the forequarters and there is a drop of 1–2 in. from sacrum to the tail-root height. There is no dominant colour and two-colour patterns are more prevalent than whole colours.

'Dalmatian' pattern is common, the incidence being between 3 and 5 per cent. The hump is generally well developed, elongated with a varying posterior overhang (Type ii, Fig. 9). The dewlap is generally not large while the sheath is not pendulous and the umbilical flap is not usually present in females. The horn is round in cross-section and 'lyre'-shaped. In females it grows in a similar manner to the Ayrshire breed, which it resembles much in all respects, including size and length. The bullock horn is similar but longer, while in bulls the horn is short, resembling that of an Ayrshire bull.

Serere type (Fig. 13, Plate 10)

These cattle are found in the Serere peninsula, in south Teso near the lake shore. They are essentially small shorthorn Zebu in respect of conformation although they attain larger size. Cows are between 40 and 43 in. in height and bullocks between 44 and 50 in. They differ, however, from the small shorthorn Zebu in other respects.

There is no particular colour pattern, whole colours and mixed being equally distributed. 'Dalmatian' pattern is not uncommon. The hump is small and dome-shaped and in many cases in females is practically non-existent (Type i, Fig. 9).

The dewlap and sheath are not large, although a few females have a small umbilical flap.

The horns are normally of small shorthorn Zebu type. Occasionally long thin horns are to be found and this horn type is not present in any other type of cattle found in Teso. This horn type is similar to that found in Ankole cattle and this factor, coupled with the very small hump, tends to suggest that these cattle are Ankole-cross Zebu imported through Bunyoro from Western Province, Uganda. Polling is very common in the area where this type is found and in some instances is as high as 15 per cent.

Kyoga type (Figs. 14, 15, Plate 10)

Mason [3] gives the origin of these cattle as being Ankole-cross Zebu. This would classify this type as being similar to the Nganda type, which are of similar origin. This type is larger than the small shorthorn Zebu type. The forehead appears broader and bulls possess characteristic wrinkles above the eyes. The chest depth is greater and the legs shorter than in the small shorthorn Zebu. Comparative measurements of this character in small shorthorn Zebu, Kyoga, and Karamojong type bullocks did not show this difference to be significant [4]. The ears are often pendulous and less erect than those of other cattle in the District. The colours are usually whole colours, either red shades or black. 'Dalmatian' pattern is not common. 'Eland' pattern is common. The hump is similar to the small shorthorn Zebu type but not normally so well developed. Occasionally it is dome-shaped. Females normally possess a well-defined umbilical flap. The horn is short and thick, sloping outwards, slightly backwards and upwards. Polling occurs but is not common.

Usuku type (Fig. 16, Plate 10)

This type is to be found in north and north-east Teso in areas adjacent to the Karamoja border and appears to be a fairly recent cross between the small shorthorn Zebu and the Karamojong type [1, 10]. They consequently vary greatly in conformation but are normally larger and heavier-boned than the small shorthorn Zebu. Whole colours predominate, roans and greys being common, while 'Dalmatian' and 'Eland' patterns are rare. The hump is larger and higher than in the small shorthorn Zebu and does not tend to overhang posteriorly (Type iii, Fig. 9). The dewlap and sheath are generally well developed but not so large as in the Kyoga type. In females an umbilical flap is common. Horn type is similar to the small shorthorn Zebu.

The relative distribution of these types within Teso District is shown in Map 1 (p. 299).

Before considering conclusions it is necessary to describe two further cattle types, namely, Karamojong and Nganda, which although they do not occur in Teso District are concerned in the origin of those types in the District:

Karamojong type (Fig. 17, Plate 10)

These remarks apply to the predominant type of cattle from the Karamoja District as seen passing through Teso *en route* for slaughter in Buganda, and to the type found in the north of Teso, along the Karamoja border. That there are many variable types to be found in Karamoja is appreciated and this factor will be considered when the possible origins of types are discussed. Mason [3] considered this type to be of East African Zebu type with much Boran blood, while Faulkner and Brown [1] describe them as large shorthorn Zebu type and likewise refer to them as being of Boran type. Compared with the small shorthorn Zebu this type is slightly larger and heavier-boned. Bullocks are on an average 1 in. taller and the head in comparison with the body size is larger. They are comparatively less deep of the chest and longer in the leg. The skin presents a loose appearance and the dewlap is very large. The sheath in males is large and pendulous while the umbilical flap is normally present in females. The ears are usually pendulous. The predominant colours are red roan, grey, and white, and if these are considered as whole colours this, along with brown and black, may be described as characteristic. 'Dalmatian' pattern is so rare as to be almost non-existent, while 'Eland' pattern is also rare. The hump is normally well developed and generally of type ii and more rarely of type iii (Fig. 9). Horn type is similar to the small shorthorn type Zebu but larger. A percentage of cattle from north Karamoja, however, have large horns which are 'necked' at the base.

Nganda type (Fig. 18, Plate 10)

This type is to be found in parts of Eastern, Western, Northern, and Buganda Provinces, Uganda. Their origin is Ankole-cross[1] Zebu.

[1] Mason [3] describes Ankole cattle as being of Sanga type with long horns, their origin being from the lateral-horned Zebu and Hamitic longhorn.

They are fairly large, beefy-type animals, the male having a well-developed sheath and dewlap and the female generally having an umbilical flap. The hump is generally of type i (Fig. 9).

Conclusions

From the above account the following tentative conclusions may be drawn concerning the origin of the present cattle in Teso District. The first cattle to enter Teso District must have been introduced some 250 years ago from Karamoja District and were probably of the type described here as 'Karamojong type'. These cattle would appear to have a separate origin from some of the cattle in north Karamoja where necked-type horns have been noted, a horn type which does not occur in Teso District. The distribution of the 'Dalmatian' marking suggests that a second introduction of cattle occurred from or through Mbale District. This is most likely to have occurred between 1800 and 1930, little introduction of cattle having occurred after 1930 as Teso was then fairly well established as an exporting district. To a lesser extent cattle were probably introduced from or through Lango District during the same period (Map 1).

These two movements would thus appear to be the origin of the small shorthorn Zebu type. The Usuku type has resulted from recent importation, mostly illegal, of Karamojong cattle from adjacent parts of Karamoja District and the resulting crosses with the small shorthorn Zebu type. A comparison shows a considerable resemblance between the Kyoga and Nganda types. Mason [3] has already referred to the Kyoga type as being Ankole-cross Zebu, i.e. Nganda type. The general conformation, size, type of horn, shape of head, size and shape of hump, pendulous sheath, and the presence of an umbilical flap in the cow all tend to support this contention, as does the introduction of cattle from Bunyoro District into this particular area of Teso District by Kaberaga in 1895. A similar comparison of the characteristics of the Serere and Nganda types plus the added weight of reports that cattle were introduced from Bunyoro to Serere county forty to fifty years ago would also lead to the conclusion that the Serere type are Nganda cattle.

There are, however, certain differences between the Kyoga and Serere types. The dewlap and sheath are much more extensive and pendulous in the Kyoga type. The drooping ears which are common in the Kyoga type are never present in the Serere type, while the hump in the Serere type is generally of type i and in the Kyoga type generally of type ii (Fig. 9). One possible explanation is that the Kyoga type is a cross of Nganda with the original Karamojong type brought to that area of Kaberamaido county by Olemmo and that a limited amount of crossing with the small shorthorn Zebu has occurred as the cattle are owned by a minority tribe, namely the Kumam, while the Serere type has originated from crossing imported Nganda type with the small shorthorn Zebu. This would account for the drooping ears and very pendulous sheath and dewlap of the Kyoga type, while the presence of the smaller hump in the Serere type would be attributable to the more recent cross with Ankole type.

Acknowledgements. The assistance of the members of the Uganda Agricultural and Veterinary Departmental staff in Teso District is most gratefully acknowledged. The author is grateful to the Director of Agriculture, Uganda, and to the Director of Veterinary Services and Animal Industry for their permission to use Departmental records and to the latter for permission to publish this article. He is indebted to Dr. J. I. Taylor, Director of Veterinary Research, Nigeria, for his encouragement and assistance during the final stages of preparation.

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FIG. 1. 'Dalmatian' colour pattern

FIG. 2. 'Eland' colour pattern

FIG. 3. Small shorthorn Zebu-type horn

FIG. 4. Kyoga-type horn

FIG. 5. Long horn

FIG. 6. Necked horn

FIG. 7. Loose horn

FIG. 8. Horn atrophy

FIG. 10. Small shorthorn Zebu cow

FIG. 11. Small shorthorn Zebu bull

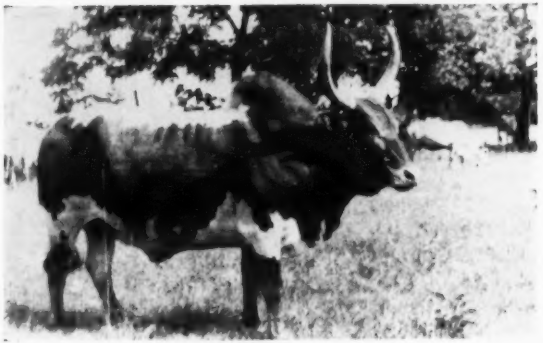

FIG. 12. Small shorthorn Zebu bullock

FIG. 13. Serere-type cow

FIG. 14. Kyoga-type cow

FIG. 15. Kyoga-type bull

FIG. 16. Usuku-type bullock

FIG. 17. Karamojong-type bullock

FIG. 18. Nganda-type cow

EFFECT OF PROLONGED AMMONIUM SULPHATE TREATMENT ON THE CALCIUM STATUS OF A TEA SOIL

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Summary

Results of an investigation into the effects of prolonged treatment with ammonium sulphate on the soil-calcium status, under the field conditions obtaining in the tea areas of north-east India, are presented in this paper. Data are recorded for soil calcium to a depth of 3 ft. from three field experiments at the Borbhetta field experimental station. It is estimated that for every 100 lb. of ammonium sulphate applied to the soil per acre, calcium (expressed as calcium carbonate) is lost at rates between 22 and 34 lb. from a soil profile of 3 ft. depth.

THE effect of different fertilizer materials on the acidity or base status of the soil has been the subject of numerous studies during the last seventy-five years. Data are available from a large number of field trials and lysimeter studies [1, 2], and laboratory methods for evaluation of the equivalent acidity or basicity of fertilizers have also been proposed [3]. Ammonium sulphate has been the most commonly used nitrogenous fertilizer for tea in north-east India for many years and the long-term effects of continuous treatment with this fertilizer on soil properties are being watched carefully at this station [4]. Results of an investigation carried out here into the effects of ammonium sulphate treatment on soil calcium under the field conditions obtaining in the tea areas of north-east India, which are somewhat different from previous data on this subject, are presented in this paper.

Three long-term manurial trials which are going on at the field experimental station at Borbhetta were made use of in this study. In these trials, which are statistically designed, the effects not only of nitrogen but also of phosphorus, potassium, and leguminous shade-tree cover are being studied, but for the purpose of this investigation, only those sub-plots which had received varying ammonium sulphate treatments, with and without shade, were sampled. The essential details about the three areas are summarized in Table 1. The soil at Borbhetta is a loamy sand of alluvial origin, having pH about 4·5, a base exchange capacity

TABLE 1. *Borbhetta Areas used for Soil-Calcium Investigation*

	Borbhetta area no.	*Shade status*	*Selected sub-plots had received, in all, ammonium sulphate at the rates specified below—lb.* N *per acre*
A	5	Half the sub-plots shaded, the others unshaded	0, 390, 780, and 1,170 over a period of 14 years
B	7	All sub-plots shaded	580 and 1,740 over a period of 20 years
C	45/47	All sub-plots unshaded	0 and 1,520 over a period of 20 years

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of about 5 m.e./100 gm., and highly unsaturated with a very low calcium content, and the other bases even lower.

The size of each sub-plot in these three field trials is about 0·04 acres. Representative soil samples were drawn by bulking about twenty borings from each sub-plot. Separate samples were collected from four depths, i.e. 0–9, 9–18, 18–27, and 27–36 inches. After air-drying, the samples were extracted with concentrated hydrochloric acid (Hall's method) and the calcium determined by a procedure similar to that described by Piper [5]. Summaries of the results obtained are given below.

A: Borbhetta area 5. This is a $2\times2\times2\times4$ factorial experiment. Jat of tea is Deamoolie, planted November 1932, spacing of the bushes being 4 ft. square. Half the number of sub-plots have been under shade from 1942, one Sau tree having been planted in each, and the others are unshaded. Manurial treatment was identical over the whole area during the period 1932–41. The sub-plots sampled had received nitrogen as ammonium sulphate at the rates 0, 30, 60, and 90 lb./acre respectively, in each spring, during the periods 1942–5 and 1947–55, manuring having been omitted in 1946. Soil samples were drawn from all plots in August 1955. The results of chemical analysis appear in Table 2.

TABLE 2. *Borbhetta Area 5, Calcium Content in Per Cent. on Dry Weight, as* Ca (*mean for four replicated plots*)

Total amount of nitrogen applied lb./acre	*Whether shaded*	*Calcium content at depth*			
		0–9 in.	*9–18 in.*	*18–27 in.*	*27–36 in.*
0 (Control)	Shade	0·032	0·029	0·018	0·012
	No shade	0·029	0·026	0·015	0·014
390	Shade	0·031	0·029	0·016	0·012
	No shade	0·028	0·027	0·014	0·014
780	Shade	0·028	0·026	0·013	0·010
	No shade	0·028	0·026	0·012	0·010
1,170	Shade	0·025	0·024	0·012	0·008
	No shade	0·022	0·024	0·012	0·008
	L.S.D., P = 0·05	0·004			

L.S.D. = Least significant difference.

Statistical analysis of the data shows that ammonium sulphate treatment has brought about a significant reduction in the calcium content of the soil and that the relation between soil-calcium status and the dose of ammonium sulphate applied is linear. Assuming that the weight of Borbhetta soil is about 3·7 million lb. per acre/foot, the amount of calcium carbonate in the different plots was calculated; the regression equation is:

$$c = (6176\pm93)-(465\pm83)\mathrm{N}$$

where c = calcium carbonate in soil profile of 3 ft. depth, in lb. per acre and N is the amount of nitrogen applied per acre, expressed in units of 390 lb., the t value being significant at P = 0·001.

B: Borbhetta area 7. This is a $2\times2\times3\times3$ factorial experiment. There are two jats of tea—light and dark leaf Silbhetta, planted November 1935, spacing of the tea bushes being $4\frac{1}{4}$ ft. triangular. The whole area has been under Sau shade from 1947 but was previously unshaded. The sub-plots sampled had received nitrogen as ammonium sulphate, in each spring, at the rates 20 and 60 lb./acre during the period 1936–46 and at 40 and 120 lb./acre respectively during the period 1947–55. Soil samples were drawn from all plots in June 1955. The results of chemical analysis appear in Table 3. Statistical analysis of the data shows that the differences in soil-calcium content with ammonium sulphate treatment are significant at P = 0·001.

TABLE 3. *Borbhetta Area 7, Calcium Content in Per Cent. on Dry Weight, as* Ca (*mean for four replicated plots*)

Total amount of nitrogen applied, lb./acre	*Jat of tea*	*Calcium content at depth*			
		0–9 in.	*9–18 in.*	*18–27 in.*	*27–36 in.*
580	Dark leaf	0·020	0·020	0·005	0·004
	Light leaf	0·025	0·025	0·008	0·004
1,740	Dark leaf	0·012	0·009	0·003	0·003
	Light leaf	0·015	0·010	0·004	trace
	L.S.D. P = 0·05	0·004			

C: Borbhetta area 45/47. This experiment has a complex design with $2\times2\times12$ treatment combinations partially confounded and repeated in three blocks. There are twelve jats of tea under trial, planted October 1936, spacing of the tea bushes being $4\frac{1}{2}$ ft. triangular. All the selected sub-plots are unshaded and all were dressed with superphosphate and sulphate or muriate of potash in 1939, 1940, and 1947. Nitrogen was applied as ammonium sulphate, in each spring, at the rates 0 and 60 lb./acre during the periods 1937–40, 1943–5, and at 0 and 100 lb./acre respectively during the period 1946–56. Unfortunately, there were some irregularities in manuring in the years 1938, 1941, and 1942 but these could not have affected results seriously. Soil samples were drawn from all plots in April 1956. The results of chemical analysis appear in Table 4. Statistical analysis of the data shows that difference in calcium content with ammonium sulphate treatment is significant at P = 0·001.

TABLE 4. *Borbhetta Area 45/47, Calcium Content in Per Cent. on Dry Weight, as* Ca (*average for 12 jats of tea*)

Total amount of nitrogen applied, lb./acre	*Calcium content at depth*			
	0–9 in.	*9–18 in.*	*18–27 in.*	*27–36 in.*
0 (Control)	0·028	0·026	0·020	0·015
1,520	0·019	0·018	0·014	0·014
L.S.D. P = 0·05	0·002			

Data for the original calcium status of these plots are not available but, assuming initial uniformity, the rates of calcium depletion were calculated and the results are presented in Table 5. In the case of Borbhetta area 5, separate calculations have been made for the shaded and unshaded areas. It is well known [6] from other studies that the yield of tea and the amounts of organic matter turned over vary considerably with the shade status and it is interesting to note that the rates of calcium loss for unshaded and shaded tea respectively, from three entirely separate Borbhetta field experiments, are consistent.

TABLE 5. *Estimates of Calcium Lost from 3 ft. of Borbhetta Soil*

Area	*Shade status*	*Expressed as lb. of* $CaCO_3$ *for every 100 lb. of ammonium sulphate applied*
Borbhetta area 5, average	Half shaded and half unshaded	25 ± 4
Borbhetta area 5	Only shaded plots	28 ± 6
Borbhetta area 5	Only unshaded plots	22 ± 7
Borbhetta area 7, average for two jats	All plots shaded	34 ± 4
Borbhetta area 45/47, average for twelve jats	All sampled plots unshaded	23 ± 3

It is necessary to emphasize here that the figures given in Table 5 refer only to a soil profile of 3 ft. depth and that the HCl extraction procedure was used. Information about possible losses of calcium through leaching from greater depths (which will be very low) or about the exact amounts of nutrients which are brought up from deeper layers and added to the top-soil (through leaf litter, &c.) is not available. It should be mentioned, on the other hand, that not all the quantities shown in Table 5 are lost as a result of the leaching action. For example, a small portion of the loss, estimated at about $1\frac{1}{2}$ lb. of calcium carbonate for unshaded tea and about half that amount for shaded tea, is actually due to removal of calcium in the plucked leaf. A portion is also presumably stored in the frames and foliage of the tea bushes and shade trees. This study was confined to calcium because the Borbhetta soil is very poor in the other bases and preliminary leaching experiments had already shown that the predominant cation lost with ammonium sulphate treatment was calcium.

It is customarily assumed that in order to make good the loss of bases resulting from application of 100 lb. of ammonium sulphate, approximately 110 lb. of calcium carbonate would have to be added to the soil. It would appear from the results of the present investigation, that the loss sustained is much lower under the field conditions obtaining in the tea areas of north-east India, which is possibly explained by the fact that these tea soils are naturally very deficient in bases.

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Glossary

Jat: Populations of seed progeny raised from a particular seed bari (orchard) are known collectively as a jat.

Sau: *Albizzia chinensis* (Osbeck) Merr., commonly used as a shade tree in the tea areas of north-east India.

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SOME PRODUCTION CHARACTERISTICS OF NATIVE CATTLE, FRIESIAN, SHORTHORN, AND THEIR CROSSES IN EGYPT

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Summary

Records collected on Friesians, Shorthorns, native cattle, and cross-bred animals over a period of ten years on two experimental stations of the Ministry of Agriculture have been analysed. Age at first calving, total milk yield, lactation period, dry period, and calving interval for different groups of cattle were studied. The results showed that native cattle were inferior in most economic characters to European breeds and cross-bred animals. Judging by the productive traits of the two pure breeds, the Friesian was more adapted to the local conditions than the Shorthorn. Grading the native cattle with the Friesian gave better results than with the Shorthorn.

THE low milk production of the native cow, coupled with the increasing demand for higher quality of milk, initiated the introduction of some foreign dairy breeds into Egypt. The purposes of such importations were to study these standard breeds under the local conditions, and to investigate the influence of grading native cattle with these pure breeds.

Khishen [1] has presented the results of his experiment on Dairy Shorthorn breeding in Egypt. Although the number of animals used in that experiment was limited in some groups, yet the work extended over a period of twenty years and showed that pure-bred animals deteriorated in production under the local conditions. Sidky [2] reported encouraging results from an importation of Friesians from Palestine in 1931. Khishen and El-Issawy [3] showed that the Jersey can be maintained successfully in the upper part of Egypt. They analysed the records of Jersey cattle and its grades, collected over a period of twenty-two years at the American College at Assiut.

The Department of Animal Production, Ministry of Agriculture, introduced Friesians, Shorthorns, Jerseys, and Guernseys in 1946. In this paper, the productive characteristics of Shorthorn, Friesian, and native cattle, and of their crosses, are presented. The dairy characters studied were: age at first calving; total milk yield; lactation period; dry period; and calving interval. Such study will throw more light on the problem of introducing foreign breeds into Egypt, and to what extent productivity of native cattle can be improved through grading.

Material and Methods

The Department of Animal Production imported between 1945 and 1948 fifty-one Friesian heifers and heifers in calf, and six bulls from

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South Africa, England, and Holland. Sixteen dairy Shorthorn cows and two bulls were imported from England in 1947. The Friesian cows and their grades were raised at the Gimmezah Agriculture Experiment Station while the dairy Shorthorns and their crosses were kept at El-Sirw. A herd of native cattle was kept on each farm.

Gimmezah and El-Sirw Experimental Farms are located in the northern part of the Delta. The climate is subtropical and the average atmospheric temperature during June, July, August, and September, which are the hottest months of the year, is 25° C. The temperature during the rest of the year ranges from 21° C. in May to 11° C. in January. The relative humidity ranges from 87 per cent. in December to 71 in May. Rain occurs only during autumn and winter months; the maximum rainfall is 8 inches during December and January. The daylight reaches the maximum (14 hours) in June, while it is only ten hours in December.

European, native, and cross-bred animals were kept under similar conditions of feeding, housing, and management. Animals were kept in open sheds during summer and fed on concentrates according to their production. In winter time they were tethered in fields of Egyptian clover until May. Cows were hand-milked twice daily, at 7 a.m. and at 3 p.m.

Data accumulated during the last ten years on Friesian, Shorthorn, native, and cross-bred animals are included in this paper. The first four normal lactations which were not affected by serious illness were used in this analysis. The numbers of animals included were 110 Friesian, 87 half-bred Friesian, 33 three-quarter Friesian, 30 Shorthorn, 145 half-bred Shorthorn, 65 three-quarter Shorthorn, and 228 native ones. Means, standard deviations, and coefficients of variability were computed for different traits studied, while the analysis of variance was applied to test the differences between groups in the characters investigated [4].

Results and Discussion

The Native Cattle

Table 1 shows the numbers of animals, the averages, and the standard deviations for the five characters studied.

Table 1 indicates that native cattle in this country resemble native stocks in other tropical and subtropical regions in production traits. Mahadevan [5] with the Sinhala cattle of Ceylon, and McLaughlin [6] with Shorthorned Zebu indigenous to Northern Sudan, found that average age at first calving was 42·4 and 40·6 months respectively. For the Zebu cattle of India and Pakistan Joshi and Phillips [7] showed that age at first calving for different Indian breeds ranged between 35 and 45 months.

Ragab *et al.* [8], with another herd of cattle in Egypt, estimated the average age at first calving as 34·3 months. This indicates that heifers in this herd tended to calve for the first time about 8 months earlier than found in the present study. The difference between the two estimates may be due to variation in management practice.

Studies on the milk production of Zebu cattle in their native land showed that the average milk yield ranged from 1,500 to 4,500 pounds per lactation [5, 6, 7, 8]. Joshi and Phillips [7] have shown that the average of some Zebu herds in India was 5,000 pounds, which is twice as much as the authors' estimate for native Egyptian cattle. The coefficient of variation was 29 compared to 39 per cent. reported for the Sinhala cattle in Ceylon [5].

The average lactation period of Egyptian native cattle was 237 days (Table 1), which is very close to 233, 242, and 231 days reported by

TABLE 1. *Productive Characters for Native Cattle*

Character	*No.*	*Mean*	*Standard deviation ±*
Are at first calving (months) .	228	42·4	11·4
Total milk yield (pounds) . .	358	2,770	801
Lactation period (days) . .	358	237	54
Dry period (days) . . .	390	170	84
Calving interval (days) . .	390	407	88

different workers on Zebu cattle [5, 6, 9]. The coefficient of variation was 22·7 per cent., lower than for most of the other characters studied.

The high and significant positive correlation (0·731) found between the lactation period and milk yield in Egyptian native cattle suggests that the short lactation period of these animals is one of the main factors for their low milk production. The regression of yield on length of lactation was 10 pounds per day. Mahadevan [5] and McLaughlin [6] reported similar results in Zebu cattle. Selecting cows with longer lactation periods will not lead to a substantial increase in milk production since the repeatability of this trait is rather low [10].

The average dry period for Egyptian native cattle was 170 days, with a coefficient of variation of 50 per cent. Data on the dry period of Zebu cattle [7] indicate that it is almost twice as long as those reported on dairy breeds in temperate regions. Mahadevan [5] was the only author to report an estimate of 122 days as the average for Sinhala cattle, while most of the other estimates for native cattle in the tropics are very close to the present results.

The average calving interval was 407 days (Table 1) with a coefficient of variation of 22 per cent. Most workers in different tropical countries [7] showed that the calving interval for native cattle exceeded 400 days, but Mahadevan [5] found the calving interval for native cattle in Ceylon to be very short—335 days—and attributed that to the freedom of the herd from reproductive troubles and to regularity of calving.

Friesian and Cross-bred Friesian Animals

Table 2 shows the numbers of animals, the averages, and the standard deviations of the five characters studied for the pure Friesian and the cross-bred animals.

The average age at first calving for the pure Friesian in Egypt is very

close to that obtained by Ragab [11] on Friesians in England, while it is shorter than the estimate of 40 months reported by Mahadevan [12] for the same breed in Ceylon. Although the difference for Friesians in temperate countries and in Egypt is negligible, yet the variability of the character is higher in tropical regions. The coefficient of variation for this trait was 28 compared to 10 per cent. reported by most workers for dairy breeds of cattle in temperate countries.

TABLE 2. *Productive Characters of Friesian and Friesian Grades*

Character	*Pure Friesian*			*½ Friesian*			*¾ Friesian*		
	No.	*Mean*	*S.D.±*	*No.*	*Mean*	*S.D.±*	*No.*	*Mean*	*S.D.±*
Age at first calving (months)	110	34·2	9·6	87	32·2	7·9	33	33·7	7·6
Total milk yield (pounds)	177	5,953	2,018	172	4,643	1,303	79	5,078	1,474
Lactation period (days)	177	370	99	172	339	91	79	338	99
Dry period (days)	153	94	81	144	120	95	67	109	76
Calving interval (days)	175	464	118	174	459	123	73	447	125

The average age at which the half-bred and three-quarter Friesian heifers calved for the first time was 32·2 and 33·7 months respectively. Coefficient of variation was 24·4 and 22·5 per cent. respectively. Differences between the Friesian and the two crosses were statistically significant ($F = 6·6$).

Although some reports showed that grading-up to European breeds was responsible for decreasing age at first calving, yet the authors' results do not show this trend. Howe [13] in Jamaica found that differences between the Friesian and its grades lacked statistical significance. The average age at first calving for the half-bred Friesian in Jamaica was 42·3 months, while Sen *et al.* [9] found 35·5 months for the same cross in India.

The average milk production of the Friesian in Egypt was about one-half of the average yield for the breed in temperate countries (Table 2). Moreover, the coefficient of variation was 34 compared to about 20 per cent. found by workers in temperate regions. Sidky [2], analysing the records of Friesians imported from Palestine, over a period of ten years, found that the average milk yield was 5,589 pounds. Mahadevan [12], on the other hand, showed that for Friesians in Ceylon the average was about 4,800 pounds only. He noted also the high coefficient of variation for milk yield of European breeds under tropical conditions.

The average milk yield for the half-bred Friesians was 4,643 pounds compared to 3,570 pounds reported by Sidky [2] for another F_1 Friesian herd in Egypt. Maule [14], compiling data of milk yield for half-bred Friesians in different tropical countries, showed that it ranged from 3,570 to 6,980 pounds per lactation. However, the estimate given by Harrison [15] for the milk yield of the F_1 half-bred Friesian in Trinidad is very close to the value found for the same cross in Egypt. The coefficient of variation for the half-bred animals—28 per cent.—was lower than that for the pure Friesian.

The increase in the Friesian blood was accompanied by an increase in the milk yield, and the three-quarter Friesian produced 5,078 pounds per lactation (Table 2). Sidky [2] found that the same cross produced 4,382 pounds, while Howe [13] reported an average of 5,220 pounds. Lecky [16], from data on the three-quarter Friesian in India, reported an average milk yield of 6,637 pounds, which varied according to the native breed used for crossing, and to the locality. The coefficient of variation in this group was very close to that obtained for the half-bred. Highly significant differences between the Friesian and the two cross-bred groups were found, with an F value of 56·4.

The average lactation period for the Friesian in this investigation was 370 days with a coefficient of variation of 27 per cent. Sidky [2], from other data on Friesians, reported a shorter lactation period (275 days). The averages for the half-bred and three-quarter Friesians were practically the same, 339 and 338 days respectively. Sidky [2] found lactation periods of the half-bred and three-quarter Friesians of 279 and 289 days respectively. The differences between the Friesians and the two cross-bred groups were significant.

The average dry periods for the Friesians, half-bred, and three-quarter Friesians were 94, 120, and 109 days respectively. The coefficient of variation was the highest among all dairy characters studied, 88, 79, and 70 per cent. respectively. Workers on Friesian cattle in temperate countries have shown that the variation was about one-half the estimate obtained in the present work, while Mahadevan [12] found for European breeds in Ceylon that the coefficient was 100 per cent., and the dry period ranged from 100 to 133 days.

The mean dry period of the half-bred Friesian in this work was longer than that found by Indian workers [9] for the same cross. Although Howe [13] concluded that there were no significant differences between animals with various amounts of Zebu blood, the authors' analyses showed that the differences between the three groups were statistically significant ($F = 4{\cdot}4$).

The calving interval for the Friesian in Egypt was 464 days (Table 1), very close to that reported for European breeds in Ceylon [12]. The coefficient of variation was 25 per cent., which is lower than other estimates for the same character in tropical countries. Lecky [16], analysing data collected on Hope Farm in Jamaica, found that the calving interval for the half-bred and three-quarter Friesians was 462 and 528 days respectively, compared to 469 and 447 days in the present work. However, differences between the three groups are not statistically significant ($F = 0{\cdot}82$).

Shorthorn and Cross-bred Shorthorn Animals

Table 3 presents numbers of animals, the averages, and the standard deviations of the characters studied, for the pure Shorthorn and half-bred and three-quarter Shorthorn animals.

The average age at first calving for the Shorthorn in Egypt was 37·7 months (Table 3). In spite of the fact that a small number of heifers were included in this group, the figure obtained is very close to that

obtained by Ragab [11] for the Shorthorn in England. Half-bred and three-quarter Shorthorns calved for the first time when they reached 36·7 and 34·2 months respectively. It is evident that increasing the Shorthorn blood was responsible for decreasing the age at first calving. Differences between the three groups were significant (F = 4·92). The coefficients of variation were 14·8 and 17 per cent. for the Shorthorn and the half-bred, but over 20 per cent. for the three-quarter-bred animals.

Khishen [1], studying Shorthorns in Egypt, reported an estimate of

TABLE 3. *Productive Characters of the Shorthorn and Its Crosses*

Character	*Pure Shorthorn*			*½ Shorthorn*			*¾ Shorthorn*		
	No.	*Mean*	*S.D.±*	*No.*	*Mean*	*S.D.±*	*No.*	*Mean*	*S.D.±*
Age at first calving (months)	30	37·7	5·6	145	36·7	6·2	65	34·2	6·8
Total milk yield (pounds)	47	4,402	1,204	311	4,649	1,382	59	4,191	1,543
Lactation period (days)	47	290	80·6	311	278	47	59	309	94·5
Dry period (days)	49	136	102	249	121	87	49	154	101
Calving interval (days)	49	426	81	249	399	89	49	463	142

5,086 pounds as the milk yield of cows imported and born in this country. This estimate is higher than the 4,402 pounds obtained from this analysis. Mahadevan [12], on the other hand, showed that in Ceylon the Shorthorn produced on the average 3,810 pounds per lactation. The coefficient of variation for this breed in the tropics is close to that obtained in its home land.

Table 3 shows that the half-bred cows gave higher milk yields than the pure and three-quarter Shorthorns. The differences, however, were not significant (F = 3·02). Khishen [1], analysing the records of Shorthorn and Shorthorn grades, found that milk yield increased with the increase of Shorthorn blood up to the three-quarter-bred animals; the average milk yield of the half-bred animals was 4,764 pounds and 5,389 for the three-quarter Shorthorn. Moreover, coefficients of variation reported by him were higher than those obtained in this investigation, and these high estimates may be due to the small numbers recorded.

The average lactation period for the Shorthorn was 290 days, which is shorter than the average for the breed in temperate and tropical countries [12]. The half-bred and the three-quarter-bred animals milked on the average for 278 and 309 days respectively. Although the coefficient of variation for the Shorthorn and the three-quarter-bred animals was similar, for the half-bred it was low, 16·9 per cent. The differences between the three groups were statistically significant (F = 6·54).

The average dry period for the Shorthorn, half-bred, and three-quarter-bred animals were 136, 121, and 154 days respectively. The value obtained for the pure-bred animals is higher than the average in temperate regions. Increasing the amount of Shorthorn blood increased the length of dry period. Differences between animals with various percentages of Shorthorn blood were significant (F = 3·29). The coefficient of variation ranged between 67 and 75 per cent.

The average calving interval for the Shorthorn was 426 days with a coefficient of variation of 19 per cent. The coefficient for some dairy breeds in Ceylon was higher, 34 per cent. [12]. The three-quarter Shorthorn showed a longer calving interval than the half-bred (Table 3) with a higher coefficient of variation. Differences between the three groups were statistically highly significant (F = 9·48).

Differences Between the Groups of Cattle in Production Traits

The data presented in Tables 1, 2, and 3 show that native cattle calved for the first time at a later age compared to the European breeds and

TABLE 4. *Analysis of Variance for Age at First Calving*

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean square*	F
Between groups . .	6	10,268	1,711·33	21·31†
Within groups . .	691	55,491	80·31	..
Total . . .	697	65,759	..	..

† Significant at P = 0·01.

cross-bred animals. Table 4 shows that differences between the seven groups were highly significant. The same result was obtained from the analysis of variance of total milk yield, lactation period, dry period, and calving interval.

The pure Friesian surpassed other groups in milk production and had the longest lactation period. The native cattle were the lowest in these respects. High correlations were obtained between lactation period and milk yield for the European and cross-bred animals, being similar to native cattle in this respect. Mahadevan [12] concluded that such high correlation exists when animals are kept under tropical or subtropical conditions, irrespective of whether the population is Zebu, European, or cross-bred animals.

The dry period for native cattle was the longest among the seven groups of animals studied, while the Friesians had the shortest. Friesian crosses were shorter than the Shorthorn crosses in the dry period, while the reverse was true for the calving interval. The pure-bred Friesian showed the longest calving interval in this study.

The dry period showed the highest variability followed by milk production, while age at first calving had the lowest variation among all groups; lactation period and calving interval were very similar in variability, intermediate between milk yield and age at first calving in this respect. The Friesians surpassed both native and Shorthorn cattle in the coefficients of variation for all traits investigated. Moreover, Friesian crosses were higher than the Shorthorn crosses in this respect.

Conclusions

The low milk production of native cattle is one of the most important problems of dairying in the tropics. Although selection among native

stock in India did help in increasing the milk yield of some breeds, such procedure is too slow to raise the level of production enough to assure a satisfactory milk supply *per capita*. It has been estimated by Asker *et al.* [17] that to increase the milk production of native cows in Egypt from 2,300 to 3,800 pounds by this means would require at least eighty years.

Introducing foreign breeds of cattle into Egypt, to grade-up the indigenous stock and to maintain the pure breeds under local conditions, has been tried by several institutions. Results presented in this paper show clearly that the native cow was inferior to the Friesian, Shorthorn, and cross-bred animals in dairy characters. The Friesians, on the other hand, as well as their crosses, were superior to the Shorthorn and its grades in most of the economic characters studied.

Although the average calving intervals of the Friesian and its crosses were longer than for the rest of the animals included in this work, the low estimates of repeatability of this character [10] suggest that most of the variations between individuals in this trait are due to environmental factors. Improving the husbandry techniques should thus eventually lead to a considerable decrease in the length of calving interval. Mahadevan [12] in Ceylon demonstrated that the calving interval of European cattle was reduced from 466 to 413 days in eight years by the gradual improvement in methods of husbandry.

The heat tolerance of the pure Friesian was found to be 80 per cent. [2], compared to 83 per cent. reported for the Shorthorn [18] in Egypt. The differences between the two breeds is thus small. Providing animals with cool and shady stables in summer will protect them from the high atmospheric temperature during this season.

When comparing the economic value of different breeds under the same conditions, it is not sufficient to study only the productive characteristics, but information on mortality rate and longevity should be considered. The authors [19] have shown that losses among Shorthorn calves from birth to three years of age amounted to 49 per cent., while they were 32 per cent. for the Friesians. This indicates that the Friesian is more adaptable to the local conditions and probably more resistant to endemic diseases than the Shorthorn. Improvement of sanitary conditions will reduce mortality among Friesians to a reasonable limit.

Results of grading-up the native cattle with these two breeds in Egypt showed different patterns. Increasing the Friesian blood was responsible for increasing the milk yield of the cross-bred animals, while this was not true in the case of the Shorthorn. This result suggests that the Friesian breed can be used successfully for grading native cattle in Egypt.

This analysis demonstrates the advantages of raising pure Friesian and also for grading-up native cattle using this breed rather than the Shorthorn in Egypt. Improving methods of feeding, management, and housing will lead to better results in milk yield and other associated dairy traits.

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STUDIES OF THE GROWTH OF CEREALS ON SEED-BEDS PREPARED BY DRY-SIEVING OF THE SOIL[1]

III. THE YIELDS OF GRAIN AND OF STRAW

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Summary

Plants of S. 172 winter oats and of Spratt Archer spring barley, which had developed from seed sown on seed-beds prepared by dry sieving of the soil, were allowed to mature and then harvested. The yields of both grain and straw were measured, together with the following characters: number of fruitful culms per plant, number of grains or spikelets (in oats) per head, 1,000-corn weight, length of straw, nitrogen content of the barley grain, and the tension required to uproot a plant at harvest time. The methods of harvesting and of dealing with the produce are described. The effects of the experimental treatments (three different dates of sowing, seed-beds made up of various aggregate-sizes of soil separates and unsieved soil, and two degrees of consolidation of the seed-bed) upon these characters were studied. Data on rainfall and soil-suction pressure were also collected.

It was found that the finest seed-bed (< 1 mm.) gave better yields than any other and that the 1 mm.–$\frac{1}{8}$ in. separate gave the poorest yields in both oats and barley. In two years out of three, barley grown on the finest seed-beds had the highest nitrogen content but in the third year the lowest. No adequate explanation for this contradictory behaviour could be found. The effect of time-of-sowing treatment on winter oats was bound up with the question of frost damage which has been discussed in a previous paper. In barley, April sowing was usually optimum for yield of grain and May sowing poorest. For large grain size March sowings were best. This sowing date also gave the lowest nitrogen content of barley grain in all years.

The consolidation-of-the-seed-bed treatment had little measurable effect on the yield characters of the plants. The results are discussed in the light of the climatic and soil moisture data.

THE cereals (sown on seed-beds made up of sieved soils) whose emergence and post-emergence behaviour have been described in the preceding papers [1, 2] were allowed to reach maturity and then harvested. This paper deals with the effects of the treatments applied—different sowing dates; different aggregate-sizes of soil separate in the seed-bed; different degrees of seed-bed consolidation—on the yields of grain and of straw obtained, and on the components of yield; it also deals with the effects of the treatments on certain other characters upon which observations were made at or subsequent to harvest time.

The severe limitation on plot size which was imposed by the experimental technique has been referred to before [1]. It was, naturally, in the harvest phase of the experiments that this limitation was most severely felt. The plot size was far below that usually recommended for use in field trials with cereals and this fact has entailed some loss of

[1] This series of papers embodies results included in a thesis submitted in part-fulfilment of the requirement for the Ph.D. degree of the University of Wales.

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precision in the comparisons of yield, especially in the 1955–6 winter oat experiment, where the number of plots was reduced through frost-killing of the later sowings. This trend to loss of precision caused by plot size was, however, counterbalanced to some extent by the more rigid control over variation in soil, sowing depth, seed rate, and fertilizer application, made possible by the micro-plot technique. Unwanted variation was also reduced by the control measures against pests and wind which are described later. It was therefore decided that the collection and analysis of harvest data would be worth while, although results as consistent as those obtained from earlier growth phases of the plants could not be expected.

Methods of Harvesting and of Handling the Produce

Soon after the plants had reached the flowering stage the plots were caged and netted with $\frac{3}{4}$-inch fruit netting to ward off birds. Warfarin baits and traps were placed around the plots to discourage field mice, which were found to be as serious a menace as birds. By these measures pest damage was reduced to a minimum. Twine was stretched along the plot edges about 1 ft. 6 in. above ground level to reduce the risk of wind laying the plants.

When the grain was judged to be ripe the plots were harvested; all the three sowings of winter oats were ripe simultaneously in 1955, but the three sowings of barley had to be cut at different times. Cutting dates for the various experiments are shown in Table 1.

TABLE 1. *Dates of Harvesting of S. 172 Winter Oats and Spratt Archer Barley sown Early, Medium, and Late*

	Year of harvest	*S. 172 winter oats* Date of sowing			*Spratt Archer barley* Date of sowing		
		Sept.	*Oct.*	*Nov.*	*Mar.*	*Apr.*	*May*
Dates of harvest	1954	..	..	..	23 Aug.	7 Sept.	14 Sept.
	1955	29 July	29 July	29 July	15 Aug.	17 Aug.	27 Aug.
	1956	30 July	*	*	14 Aug.	24 Aug.	7 Sept.

* Destroyed by frost heaving.

The variation in the dates for cutting barley reflects the great differences in weather conditions during the growing and harvesting seasons of the three years. The rainfall in inches per week between 1 May and 30 September for each of the years 1954, 1955, and 1956 is plotted in histogram form on Fig. 1. Also plotted are the suction pressures developed by the soil, in cm. of mercury, as recorded by tensiometers of the Bourdon-gauge type. The tensiometers were read daily but the readings have been summarized and are plotted as twice-weekly records. It is convenient to look upon each season as divided into the growing period (May and June) and the ripening and harvest period (July and August). During the growing periods the total rainfall in inches was: 1954, 7·4; 1955, 9·4; 1956, 3·4. Whereas 1956 was a dry growing period and 1955 clearly a wet one with some rain every week, the 1954 growing

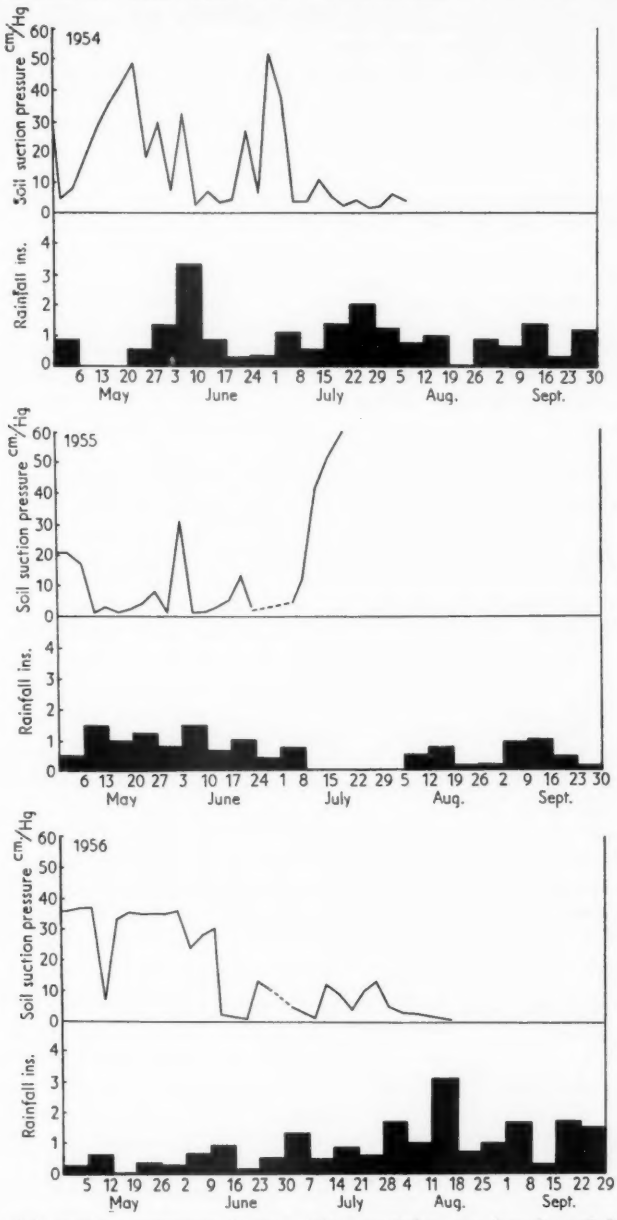

FIG. 1. Soil suction pressures from 1 May until harvest (condensed from daily readings at 9 a.m.) and weekly rainfall from 1 May to 30 September, years 1954, 1955, and 1956.

period had a fair quantity of rain but most of it fell in one intense spell with dry periods before and after.

The differences, from the point of view of availability of soil moisture, are well brought out by the graphs of soil suction pressure. During the ripening and harvesting periods the total rainfall in inches was: 1954, 9·1; 1955, 2·3; 1956, 10·6. The picture here is simpler; 1955 was a very fine dry harvest but 1954 and 1956 were wet ones. It will be observed that the tensiometers ran off their upper range in mid-July 1955 and readings were abandoned. Readings were taken into August in both of the wet years and show low suction pressures. Reference is made to this figure during the discussion of harvest results.

The operation of harvest was carried out as follows: The two outside rows were cut with shears and discarded, leaving the four inner rows. No end-of-row discards were made as the plots were separated only by the width of a board and no end effects were apparent. It was felt that the loss in plant number through end-of-row discards would be serious in such small plots and that the possible loss of precision through including the end plants was likely to be very small. The guard plot at each end of each block was, of course, cut and discarded. At this point a check count of the standing plants was made to determine whether there had been an appreciable loss of plants between the May count and harvest; no difference greater than two or three plants was ever recorded. Since a difference of this size might well have been attributable to the difficulty of counting mature plants *in situ* (even though accurately spaced) it was considered better to take the May count, which was known to be accurate, as representing the number of plants at harvest. Ten plants in the outer eastern row were uprooted by attaching a loop of string to the base of each plant in turn and then pulling it up with a spring balance. The peak tension required to uproot the plant was recorded and the mean of the ten readings used as plot estimate for anchorage. It would, no doubt, have been preferable to take a larger sample and to use a random method of choosing it, but time factor and difficulty of access to inner plants made this impracticable. The remaining plants were cut about 2 in. above ground level and the ten uprooted plants were trimmed to leave a similar stubble and added to the sheaf. The sheaves were spread out on racks indoors and allowed to reach moisture equilibrium with the atmosphere. From these sheaves, data were collected as follows:

(*a*) The culms bearing grain were counted and recorded as 'fruitful culms'.

(*b*) By a quartering method a sample of about twenty culms was drawn from each plot sheaf.

  (i) Each culm was measured from its cut end to the base of the head in centimetres; the mean of the twenty measurements was recorded as 'length of straw'.

  (ii) The grains (or spikelets of oats) were counted on each head and the mean recorded as 'grains per head' or 'spikelets per head'.

(*c*) The samples were rebulked with the remaining plot produce and the whole weighed.

(*d*) The sheaves were threshed in a bench thresher and the grain winnowed and weighed.

(*e*) The straw weight was found by difference.

(*f*) The 1,000-corn weight was determined by weighing 100 grains (drawn at random) on an analytical balance.

(*g*) Samples of the barley grain were analysed for nitrogen content. This was done because it was desired to measure the effect of treatments on the quality of barley from a malting viewpoint.

No attempt was made to count the number of oat grains per spikelet.

All these data have been analysed statistically and the variation allocated to treatment, replicates, and error. From the latter, coefficients of variation have been computed for each category of data in each experiment. These measures of the precision of the experiments are given in Table 2.

TABLE 2. *Coefficients of Variation* $\left(\frac{\sqrt{(Mean\ square\ error)} \times 100}{General\ mean}\right)$ *of the Various Experiments*

Category of harvest data	*Winter oats experiments*				*Spring barley experiments*					
	1954–5		*1955–6*		*1954*		*1955*		*1956*	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
	%	%	%	%	%	%	%	%	%	%
Yield of grain	9·0	10·4	..	24·0	12·6	8·5	13·1	9·1	9·6	4·5
Yield of straw	13·7	10·4	..	21·0	16·3	11·4	19·0	9·1	20·7	7·3
Fruitful culms per plant	13·9	11·1	..	12·1	5·6	7·9	20·9	8·8	7·1	4·6
Grains or spikelets per head	17·2	11·0	..	11·7	1·6	3·9	1·8	2·7	7·6	3·5
1,000-corn weight	8·3	3·4	..	4·6	7·1	2·8	2·4	2·4	3·8	1·9
Length of straw	7·1	4·9	..	6·8	7·3	2·9	7·5	3·0	7·5	4·4
Nitrogen %	..	..	..	..	1·4	5·2	1·7	3·9	9·5	2·6
Anchorage	8·6	18·7	..	20·4	20·9	11·4	..	..	17·7	14·0
Number of plots	72		24		72		72		36	

A. C.V. based on whole-plot error—applicable to time of sowing treatment.
B. C.V. based on sub-plot error—applicable to all other treatments and interactions.

According to Wishart and Sanders [3] the coefficien tof variation should not exceed 10 per cent. for yield data from cereal plots. With this figure as a guide the precision of the harvest data, as revealed in Table 2, may be commented upon as follows:

(i) Winter oats experiments show greater variability in data than spring barley even when allowance is made for the special circumstances in the 1955–6 experiment (this was in the nature of a salvage operation).

(ii) Estimates based on plot measurements of yield gave greater errors than those based on samples. This merely reflects the smaller inherent variability of the characters which were estimated

by sampling, such as number of grains per head in barley, 1,000-corn weight and length of straw. It may be said that the sampling technique used for estimating the components of yield and length of straw was generally efficient. Larger samples would probably have given a better estimate of spikelet number in oats, which character is much more variable than grain number in barley.

(iii) *A* errors are larger (in most cases) than *B* errors, i.e. time-of-sowing comparisons are less precise than the other comparisons. This was foreseen and a deliberate sacrifice made in order to keep the number of plots within limits which could be handled.

(iv) Errors in the anchorage data are large and there can be little doubt that information on this aspect has been lost as a result. Larger samples were needed.

(v) The plot-to-plot error variation in the spring 1956 experiment is surprisingly low in view of the fact that less degrees of freedom were available for error than in the comparable 1954–5 experiments. It is possible that the spraying applied to this experiment for weed control may have reduced unwanted variation attributable to weed infestation.

(vi) In view of the size of plots and excluding the winter oats 1955–6 experiment the coefficients of variation are not excessively high.

It is known that spacing of cereals has a profound effect on yield and on its components, e.g. on fruitful culms per plant and number of grains per head [4]. For this reason co-variance of yield and its components on number of plants per plot was carried out for all years. In most cases no significant regression of these characters on plant number was established. This finding reflects the general high level of plant population found, especially in the barley experiments. Correction of harvest data for number of plants has been made wherever significant regressions occurred (mostly in winter oats 1954–5 where frost damage had produced large differences in plant number on the different soil treatments, and in the spring barley 1956 experiment where the coarsest-sieved seed-beds had a consistently lower plant population).

Results: 1. Observations on Yield

S. 172 Winter Oats

Yield of grain. (*a*) *1954–5 experiment.* The complete experiment was harvested and the actual yields of grain (expressed as cwt./acre), together with these yields corrected on the basis of equal plant numbers per plot, are given in Table 3.

Despite the handicap of lower number of plants, the finest seed-bed produced a significantly higher yield than any other (except the $\frac{3}{8}$–$\frac{1}{2}$ in. seed-bed). When allowance is made for the disparity in plant number the superiority of the 1 mm. seed-bed is even more marked. The next best yield is on the coarsest-sieved seed-bed and the lowest yield on the 1 mm.–$\frac{1}{8}$ in. seed-bed. The effect of sowing date on yield of grain is shown in Table 4.

TABLE 3. *Effect of Aggregate-Size of Soil Separate on the Yield of Grain of S. 172 Winter Oats, 1954–5*

(*Means of 12 Plots*)

	1	2	3	4	5	6	*Least significant difference*	
Aggregate-size of soil separate	< 1 *mm.*	1 *mm.*–$\frac{1}{8}$ *in.*	$\frac{1}{8}$–$\frac{1}{4}$ *in.*	$\frac{1}{4}$–$\frac{3}{8}$ *in.*	$\frac{3}{8}$–$\frac{1}{2}$ *in.*	*Unsieved*	P = 0·01	P = 0·05
A. Number of plants per plot	68·2	81·7	83·4	80·7	77·0	79·4	6·34	4·88
B. Yield of grain cwt./acre	21·6	18·3	19·9	19·7	20·7	19·7	..	1·71
B corrected for A	23·4	17·7	19·0	19·4	20·9	19·6	*	*

* L.S.D. for corrected means P = 0·01 col. 1–col. 6: 2·55.
,, ,, ,, P = 0·01 col. 2–col. 5: 2·09.
,, ,, ,, P = 0·05 col. 3–col. 5: 1·67.
No significant differences between cols. 4, 5, and 6.

TABLE 4. *Effect of Time of Sowing on the Yield of Grain of S. 172 Winter Oats 1954–5*

(*Means of 24 Plots*)

Time of sowing	*Sept.*	*Oct.*	*Nov.*	*Least significant difference*	
				P = 0·01	P = 0·05
Yield in cwt./acre .	21·0	22·6	16·4	..	2·24

In assessing the relative merits of October versus September sowing it should be borne in mind that in 1955–6, due to frost heaving, the October and November sowings were a total loss. Seed-beds consolidated at sowing time in a manner already described [1] yielded more grain than seed-beds not so consolidated. This effect appears in Table 5 where it may also be observed that when correction is made for the greater number of plants on the unconsolidated plots the advantage in yield of the consolidated plots reaches significance at the level P = 0·01.

TABLE 5. *Effect of Consolidation of the Seed-bed on the Yield of Grain of S. 172 Winter Oats*

(*Means of 36 Plots*)

Seed-bed treatment	*Not consolidated*	*Consolidated*	*Least significant difference*	
			P = 0·01	P = 0·05
A. No. of plants per plot	79·9	76·9	..	2·81
B. Yield of grain in cwt./acre . .	19·5	20·5	..	0·99
B corrected for A . .	19·2	20·8	1·21	..

(*b*) *1955–6 experiment.* The harvest data for this experiment are taken from the September sowing only. The effect of soil treatment on the yield of grain just reached significance at P = 0·05. The means

are shown in Table 6. Here again the finest seed-bed gave the highest yield, being superior to all others except the $\frac{1}{8}$–$\frac{1}{4}$ in. and the unsieved soil.

TABLE 6. *Effect of Aggregate-Size of Soil Separate on the Yield of Grain of S. 172 Winter Oats, 1955–6*

(*Means of 4 Plots*)

Aggregate-size of soil separate	< 1 mm.	1 mm.–$\frac{1}{8}$ in.	$\frac{1}{8}$–$\frac{1}{4}$ in.	$\frac{1}{4}$–$\frac{3}{8}$ in.	$\frac{3}{8}$–$\frac{1}{2}$ in.	*Unsieved*	*Least significant difference*	
							P = 0·01	P = 0·05
Yield of grain in cwt./acre .	25·0	16·2	21·3	16·4	14·1	19·9	..	7·03

The components of yield of grain. Yield of grain may be considered as being built up of a number of component parts: Number of Plants; Number of Fruitful Culms per Plant; Number of Grains per Culm; Weight of a Grain. The product of these (expressed in suitable units) gives an estimate of the yield actually obtained. How closely this estimate of yield will correspond to the yield obtained by threshing the total produce will depend on:

(i) How representative the samples (on which are based the estimates of, e.g., Number of Grains per head) are of the whole population.
(ii) On the harvest and threshing losses sustained by the whole produce.

In oats if spikelets per head are counted and 1,000-grain weight obtained, no true estimate of yield can be made unless the mean number of grains per spikelet is also known. The only treatment which consistently affected these factors of yield in oats was the aggregate-size of soil-separate treatment. The effects of this are shown in Table 7.

TABLE 7. *Effect of Aggregate-Size of Soil Separate on some of the Components of Grain Yield in S. 172 Winter Oats 1954–5 and 1955–6*

(*Means of 12 samples 1954–5; of 4 samples 1955–6*)

Aggregate-size of soil separate		< 1 mm.	1 mm.–$\frac{1}{8}$ in.	$\frac{1}{8}$–$\frac{1}{4}$ in.	$\frac{1}{4}$–$\frac{3}{8}$ in.	$\frac{3}{8}$–$\frac{1}{2}$ in.	*Unsieved*	*Least significant difference*	
								P = 0·01	P = 0·05
Number of plants per plot	1954–5	68·2	81·7	83·4	80·7	77·0	79·4	6·34	4·88
	1955–6	90·5	88·3	85·8	84·0	84·8	83·3	n.s.	n.s.
Number of fruitful culms per plant	1954–5	1·69	1·42	1·39	1·45	1·54	1·46	0·174	0·134
	1955–6	1·66	1·48	1·62	1·59	1·49	1·55	n.s.	n.s.
Number of spikelets per head	1954–5	29·3	24·8	24·3	25·2	26·7	24·3	2·99	2·30
	1955–6	34·9	24·0	30·8	25·7	23·0	31·8	7·31	5·17
Weight of 1,000 grains in gm.	1954–5	32·1	32·4	32·4	32·7	32·8	32·3	n.s.	n.s.
	1955–6	30·1	30·8	30·3	29·5	30·1	29·0	n.s.	n.s.

In both experiments it appears that the higher yields of grain in fine seed-beds, referred to in Tables 3 and 6, were chiefly made up by larger numbers of fruitful culms per plant and larger numbers of spikelets per

head on the plants grown on these seed-beds. There can be little doubt that, in the 1954–5 experiment, part of this effect on culm and spikelet number can be attributed to the lower plant number on fine plots, despite the fact that no significant correlation between these factors and plant number could be detected. This argument (that wider spacing caused part of the observed increase in culms and spikelets on fine plots) cannot, however, apply to the 1955–6 experiment where numbers of plants were somewhat higher on the finest seed-beds yet a similar effect on culm number and spikelet number was detected, though not reaching significant levels in the former character. Thousand-grain weight does not appear to be affected significantly by the treatments applied. The relationships between yield and its components are shown diagrammatically in Fig. 2.

In the 1954–5 experiment a significant interaction was detected between the effects of time of sowing and of aggregate-size of soil separate upon number of spikelets per head. The relevant data appear on Fig. 3 where it will be noted that: (i) disregarding the finest seed-beds, there were fairly consistent differences as between one time of sowing and another; although these failed to reach significance, it appears likely that they would have done so with an experimental layout designed to test this; (ii) again disregarding the finest plots there appeared to be an increasing tendency to get high spikelet numbers on coarser plots as sowing became later; (iii) the number of spikelets per head on plants on the finest plots reflected the increased space per plant which was to be found on the third sowing as a result of plant destruction by frost heaving. It would appear that the survivors were able to compensate for diminution in number by a great increase in spikelets per head. It seems possible that many of these differences stem from the differential plant damage sustained under the various treatments during the winter.

The yield and length of straw, 1954–5 and 1955–6. The influence of aggregate-size of soil separate and consolidation of the seed-beds on the yield and length of straw are shown in Tables 8 and 9.

TABLE 8. *Effect of Aggregate-Size of Soil Separate on the Yield and Length of Straw of S. 172 Winter Oats*

(*Means of 12 Plots 1954–5; of 4 Plots 1955–6*)

Aggregate-size of soil separate		< 1 *mm.*	1 *mm.*–$\frac{1}{8}$ *in.*	$\frac{1}{8}$–$\frac{1}{4}$ *in.*	$\frac{1}{4}$–$\frac{3}{8}$ *in.*	$\frac{3}{8}$–$\frac{1}{2}$ *in.*	*Unsieved*	*Least significant difference* P = 0·01	P = 0·05
Yield of straw in cwt. per acre	1954–5	26·9	23·4	24·7	24·1	26·3	23·0	2·80	2·15
	1955–6	44·2	23·1	31·0	27·7	24·1	34·1	14·13	9·99
Length of straw in cm.	1954–5	54·3	51·1	52·2	52·1	53·6	52·0	n.s.	n.s.
	1955–6	53·6	45·0	48·2	47·4	45·4	51·7	..	5·09

The greatest yield of straw and the longest straw (these are closely correlated) was carried by the finest seed-beds. The behaviour of plants on unsieved soil and the $\frac{3}{8}$–$\frac{1}{2}$ in. seed-beds was erratic. Unsieved soil occupied a low position in 1954–5 and a high one in 1955–6—the reverse

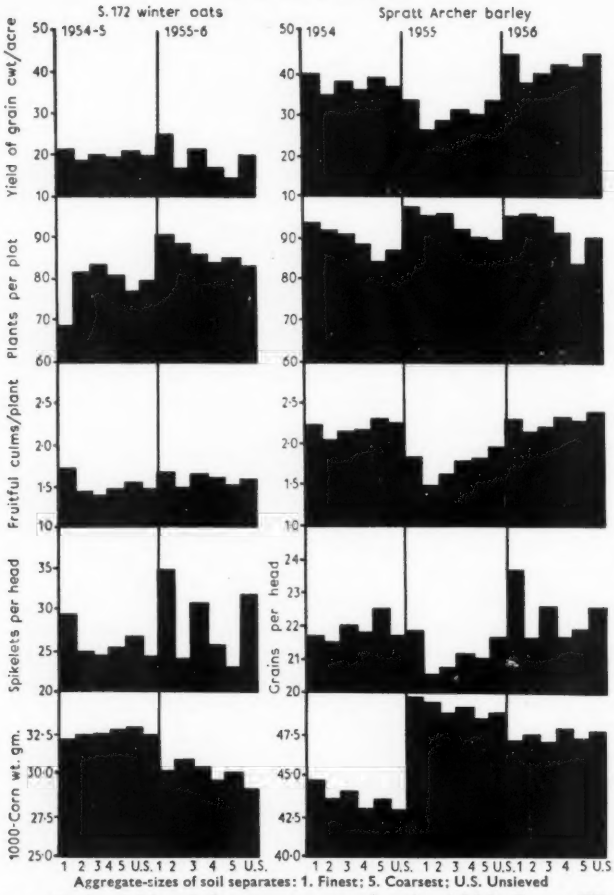

FIG. 2. Grain yield and the components of grain yield in S. 172 Winter Oats and Spratt Archer Barley 1954–56.

TABLE 9. *Effect of Consolidation of the Seed-bed on Yield and Length of Straw in S. 172 Winter Oats*

(*Means of 12 Plots 1954–5; of 4 Plots 1955–6*)

Seed-bed treatment		*Not consolidated*	*Consolidated*	*Least significant difference* P = 0·01	P = 0·05
Yield of straw in cwt./acre	1954–5	23·8	25·6	1·62	..
	1955–6	31·3	29·8	n.s.	n.s.
Length of straw in cm.	1954–5	51·6	53·5	1·59	..
	1955–6	48·1	49·0	n.s.	n.s.

is true of the $\frac{3}{8}$–$\frac{1}{2}$ in. separate. There does not seem to be any pattern in these results except for the consistent superiority of the finest seed-beds and the consistent inferiority of the finest-but-one group.

As regards Table 9 the result for 1954–5 is in agreement with that already described for grain in Table 5.

Spratt Archer Spring Barley

Yield of grain. Since the experiments on barley are reasonably uniform, in that no plots were lost from any experiment, the results of the three years' work will be considered together. Correction of yield for plant number was found to be unnecessary in all the barley experiments. The yields obtained on the various soil treatments are shown in Table 10.

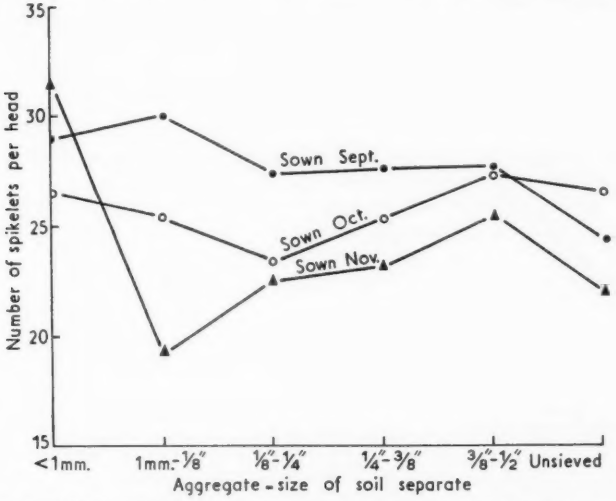

FIG. 3. The effect of time of sowing and aggregate-size of soil separate on the number of spikelets per head in S. 172 winter oats 1954–5. (Each point is the mean of 4 plots.)

TABLE 10. *Effect of Aggregate-Size of Soil Separate on the Yield of Spratt Archer Barley*

(*Means of 12 plots 1954 and 1955; of 6 plots 1956*)

Aggregate-size of soil separate		*< 1 mm.*	*1 mm.–$\frac{1}{8}$ in.*	*$\frac{1}{8}$–$\frac{1}{4}$ in.*	*$\frac{1}{4}$–$\frac{3}{8}$ in.*	*$\frac{3}{8}$–$\frac{1}{2}$ in.*	*Unsieved*	*Least significant difference* P = 0·01	P = 0·05
Yield of grain in cwt./acre	1954	39·4	34·4	37·4	35·5	38·0	35·8	3·34	2·57
	1955	33·1	25·6	27·7	30·1	29·3	32·4	2·86	2·20
	1956	43·7	36·8	38·8	40·9	40·6	43·7	2·22	1·60

In all years, plants on the finest seed-beds significantly outyielded those on all other seed-beds except the unsieved soil, which they significantly outyielded in 1954 only. The finest-but-one seed-bed was invariably the lowest yielder. There do not appear to be any consistent

differences between yields on the three coarser-sieved separates. In two years out of three the time of sowing had a significant effect on yield of grain as may be observed from Table 11.

TABLE 11. *Effect of Sowing Date on the Grain Yield of Spratt Archer Barley*

(*Means of 24 Plots 1954 and 1955; of 12 Plots 1956*)

Time of sowing		*Mar.*	*Apr.*	*May*	*Least significant difference*	
					P = 0·01	P = 0·05
Yield of grain in cwt./acre	1954	44·7	37·8	27·7	..	5·76
	1955	29·2	36·7	23·3	..	4·85
	1956	38·6	43·9	39·7	n.s.	n.s.

The effect of sowing date on yield obviously depends to a great extent on the weather conditions in spring. Here in two years out of three early April sowing gave the highest yield but in one year (when presumably weather conditions were suitable) mid-March sowing gave the best result. It is probably of rather more importance to note, however, that, in two years out of three, May sowings were markedly inferior to either March or April sowings. From Fig. 4, which shows the combined effect of size of soil separate and time of sowing on yield of grain, it would seem that in 1955 the advantage of the finest plots and unsieved plots (which contain a proportion of the finest soil) was greater where yields were highest, i.e. in the April sowing. In the May sowing, where poor yields were obtained, the differences between yields on different sizes of soil separate were less.

Attention may be drawn at this point to the general level of yield. This is very high as might be expected in plants cared for under intensive conditions.

The components of grain yield. The effects of different aggregate-size of soil separate in the seed-bed on the various component parts of grain yield are demonstrated by the mean values in Table 12.

Plant number per plot did not vary within such wide limits as with winter oats, but the coarsest-sieved seed-beds and the unsieved soil generally carried 5–10 per cent. less plants than the remaining seed-beds. This has been discussed in a previous paper [2]. Correction of the means of culms per plant and grain per head for plant number has been carried out on the 1956 data, where a significant regression was established. The lowest number of fruitful culms per plant was invariably found on the 1 mm.–$\frac{1}{8}$ in. separate, while the highest numbers were found on the finest seed-bed and on unsieved soil.

Significant differences between soils in respect of number of grains per head were recorded in 1955 and 1956 but not in 1954. Again the 1 mm.–$\frac{1}{8}$ in. plots occupied the lowest positions and the < 1 mm. plots the highest with unsieved soil also high.

As already observed in winter oats, the 1,000-grain weight does not seem to have been very responsive to the soil treatments applied. In

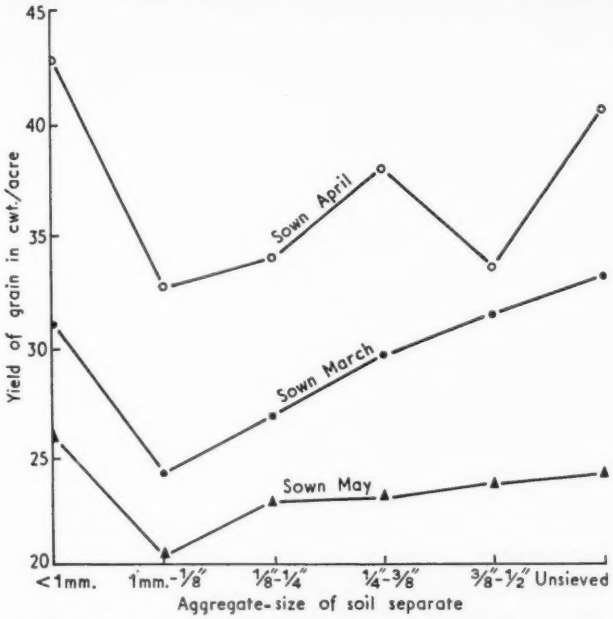

FIG. 4. The effect of time of sowing and aggregate-size of soil separate on the yield of grain of Spratt Archer Barley in 1955. (Each point is the mean of 4 plots.)

TABLE 12. *Effect of Aggregate-Size of Soil Separate in the Seed-bed on the Component Parts of Grain Yield in Spratt Archer Barley*

(*Means of 12 samples 1954 and 1955; of 6 samples 1956*)

		1	2	3	4	5	6		
Aggregate-size of soil separate		< 1 *mm.*	1 *mm.*–¼ *in.*	¼–½ *in.*	½–⅜ *in.*	⅜–½ *in.*	*Unsieved*	*Least significant difference* P = 0·01	*Least significant difference* P = 0·05
Number of plants per plot	1954	93·0	91·4	90·3	87·9	83·6	86·2	4·32	3·32
	1955	97·0	94·4	95·1	91·5	89·1	88·2	2·86	2·20
	1956	94·2	94·7	94·0	90·2	82·2	88·7	6·67	4·81
Number of fruitful culms per plant	1954	2·28	2·07	2·16	2·14	2·22	2·20	n.s.	n.s.
	1955	1·81	1·49	1·61	1·77	1·79	1·93	0·11	0·09
	1956	2·27	2·11	2·18	2·30	2·24	2·36	*a*	*a*
Number of grains per head	1954	21·7	21·5	22·0	21·8	22·5	21·7	n.s.	n.s.
	1955	21·8	20·5	20·7	21·1	21·0	21·6	0·61	0·47
	1956	23·6	21·6	22·5	21·6	21·8	22·5	*b*	*b*
Weight of 1,000 grains in gm.	1954	44·5	43·5	43·8	42·8	43·4	42·8	1·3	1·0
	1955	49·6	49·4	48·7	49·0	48·3	48·6	n.s.	n.s.
	1956	47·0	47·3	46·8	47·6	47·1	47·4	n.s.	n.s.

a L.S.D. (P = 0·01) between corrected means col. 1–col. 2 = 0·12.
" " " " " col. 2–col. 6 = 0·13.
b L.S.D. (P = 0·01) " " " col. 1–col. 4 = 1·25.
" " (P = 0·05) " " " col. 1–col. 2 = 1·25.
" " " " " col. 1–col. 5 = 1·40.
" " " " " col. 6–col. 4 = 0·84.

1954 only, plants on fine seed-beds carried significantly larger grains than did those on unsieved soil and those on the coarser seed-beds.

The effect of the seed-bed treatments on yield was chiefly through the effect of those treatments on culm number and number of grains per head.

The way in which these components of yield were influenced by the time of sowing the barley is shown in Table 13.

TABLE 13. *Effect of Sowing Date on the Component Parts of Grain Yield in Spratt Archer Barley*

(*Means of 24 Plots 1954 and 1955; of 12 Plots 1956*)

Time of sowing		*Mar.*	*Apr.*	*May*	*Least significant difference* P = 0·01	P = 0·05
Number of plants per plot	1954	88·4	90·4	87·4	n.s.	n.s.
	1955	94·9	90·0	92·8	n.s.	n.s.
	1956	89·2	90·3	92·4	n.s.	n.s.
Number of fruitful culms per plant	1954	2·30	2·29	1·95	..	0·15
	1955	1·56	2·02	1·64	n.s.	n.s.
	1956	2·05	2·29	2·39	n.s.	n.s.
Number of grains per head	1954	24·0	21·3	20·2	1·03	0·45
	1955	21·8	22·2	19·3	1·11	0·48
	1956	21·8	24·0	21·0	n.s.	n.s.
Weight of 1,000 grains in gm.	1954	46·6	43·4	40·7	..	3·82
	1955	49·5	48·6	48·7	n.s.	n.s.
	1956	50·2	46·8	44·6	..	3·12

Whereas the influence of aggregate-size of soil separate on yield was chiefly exerted through the number of fruitful culms and the number of grains per head, the influence of different sowing dates on yield appears to be exerted chiefly through the number of grains per head and, to a smaller extent, through differences in grain size. The number of culms per plant was not consistently affected by changes in date of sowing—differences reaching significance only in 1954. March sowing gave the largest grains in all years; this is worthy of note from the point of view of quality, and is referred to later in conjunction with observations on nitrogen content. In two years out of three April sowings gave the highest number of grains per head. May sowings gave the least number of grains per head in all years and the smallest grains in two years out of three.

The yield and length of straw. The yield of barley straw was generally high. The effects of the sieving treatments on yields are shown in Table 14 and their effect on length of straw in Table 15.

The 1 mm.–$\frac{1}{8}$ in. separate gave the lowest yield of straw in all years but the difference between treatments were not significant in 1954. The finest separate and the unsieved soil gave the highest yield, with the remaining aggregate sizes in an intermediate position and not, in general, differing significantly from one another.

TABLE 14. *Effect of Aggregate-Size of Soil Separate on the Straw Yield of Spratt Archer Barley*

(*Means of 12 Plots 1954 and 1955; of 6 Plots 1956*)

Aggregate-size of soil separate		*< 1 mm.*	*1 mm.–$\frac{1}{8}$ in.*	*$\frac{1}{8}$–$\frac{1}{4}$ in.*	*$\frac{1}{4}$–$\frac{3}{8}$ in.*	*$\frac{3}{8}$–$\frac{1}{2}$ in.*	*Unsieved*	*Least significant difference*	
								P = 0·01	P = 0·05
Yield of straw in cwt./acre	1954	42·3	36·9	41·2	38·2	39·9	39·1	n.s.	n.s.
	1955	44·9	32·6	36·7	39·2	38·2	42·8	3·77	2·90
	1956	47·4	40·6	44·9	44·8	47·3	48·9	5·71	4·12

TABLE 15. *Effect of Aggregate-Size of Soil Separate on the Length of Straw of Spratt Archer Barley*

(*Means of 12 samples 1954 and 1955; of 6 samples 1956*)

Aggregate-size of soil separate		*< 1 mm.*	*1 mm.–$\frac{1}{8}$ in.*	*$\frac{1}{8}$–$\frac{1}{4}$ in.*	*$\frac{1}{4}$–$\frac{3}{8}$ in.*	*$\frac{3}{8}$–$\frac{1}{2}$ in.*	*Unsieved*	*Least significant difference*	
								P = 0·01	P = 0·05
Length of straw in cm.	1954	80·5	78·5	79·0	78·1	79·5	77·5	2·43	1·87
	1955	86·7	77·5	80·8	81·7	80·6	83·8	2·64	2·03
	1956	75·9	71·2	73·9	70·8	73·3	75·7	n.s.	n.s.

The straw on the finest (< 1 mm.) plots was consistently longer than that on any of the other plots; this difference was particularly great in 1955 but smaller in 1954 and 1956, differences failing to reach significant levels in the latter year. It may be pertinent to note that in the dry summer (1955) the 1 mm.–$\frac{1}{8}$ in. separate carried much shorter straw than any other separate but that in the wet summers (1954 and 1956) the inferiority of this separate was much less marked.

Variability of yield and length of straw was too great to allow any differences which may have been attributable to time of sowing to reach significant levels.

Results: 2. Other Observations made at, or subsequent to, Harvest

Percentage of Nitrogen in the Barley Grain

As already mentioned in the introduction to this paper, observations were made on the N content of the barleys harvested, in an attempt to assess one aspect of their malting quality. It was found that in this respect, the most important of the treatments applied was the different sowing dates. This is brought out in Table 16.

TABLE 16. *Effect of Different Sowing Dates on the Nitrogen Content of Spratt Archer Barley*

(*Means of 24 samples 1954 and 1955; of 12 samples 1956*)

Time of sowing		*Mar.*	*Apr.*	*May*	*Least significant difference*	
					P = 0·01	P = 0·05
% Nitrogen in grain	1954	1·51	1·84	1·93	0·069	0·030
	1955	1·36	1·37	1·49	0·069	0·030
	1956	1·45	1·44	1·64	n.s.	n.s.

March sowings gave low N content in all years and April sowings in two years out of three. May sowings invariably gave higher values than March or April sowings. This finding is in accord with the conclusions of other workers [5] that late sowings give barley grain with higher N content. Evidence from several sources [5, 6] has established that an increased May–June rainfall results in grain with lower nitrogen content. July–August rainfall has little effect on this character but, of course, a profound effect on certain other aspects of grain quality. From Table 16 in conjunction with Fig. 1 it will be seen that this effect of May–June rainfall is apparent in these experiments. The year with a wet May–June (1955) has given grain with a lower nitrogen content than in the other years. One would have expected, however, that in 1956 the grain would have had higher N content than in 1954, but this is not the case. It is possible that some more subtle distinction concerning the way in which the dry and wet spells were distributed over the periods was responsible, but there is no means of testing this speculation except by controlled experiments using different watering régimes.

The effect of the seed-bed grading on the N content is shown in Table 17.

TABLE 17. *Effect of Aggregate-Size of Soil Separate in the Seed-bed on the Nitrogen Content of Spratt Archer Barley*

(Means of 12 samples 1954 and 1955, of 6 samples 1956)

Aggregate-size of soil separate		*< 1 mm.*	*1 mm.–$\frac{1}{8}$ in.*	*$\frac{1}{8}$–$\frac{1}{4}$ in.*	*$\frac{1}{4}$–$\frac{3}{8}$ in.*	*$\frac{3}{8}$–$\frac{1}{2}$ in.*	*Unsieved*	*Least significant difference*	
								P = 0·01	P = 0·05
% Nitrogen in grain	1954	1·85	1·74	1·72	1·77	1·75	1·73	..	0·075
	1955	1·45	1·42	1·39	1·39	1·38	1·42	..	0·045
	1956	1·46	1·53	1·50	1·51	1·56	1·52	0·066	0·048

Here surprisingly enough (in view of popular opinion) the finest seed-bed gave the highest N content in two seasons out of three. In the third season, however, the position was completely reversed, the coarsest seed-beds carrying the barley with the highest N content and the finest that with the lowest. It seems likely that here again further work with controlled watering régimes on the separates of different fineness is required if any logical interpretation is to be found. In Fig. 5 may be seen the combined effect of sowing date and type of seed-bed.

Tension Required to Uproot Plants of Oats and Barley at Harvest

The technique used to obtain these data has been described under 'Methods'. Also, it has been pointed out that the coefficients of variation of the data indicated that a larger sample would probably have given more reliable results. No data were obtained from the barley in the 1955 season because it was found that the tensions required to uproot were either beyond the tensile strength of the straw or outside the capacity of the spring balance used for this work (reading up to 25 lb.). Data obtained from the remaining experiments are presented in Tables 18 and 19.

From Table 18 it may be concluded that the force required to uproot a plant was consistently greater where the plant grew on the finest seed-beds. There appears to be a slight trend for plants on unsieved seed-

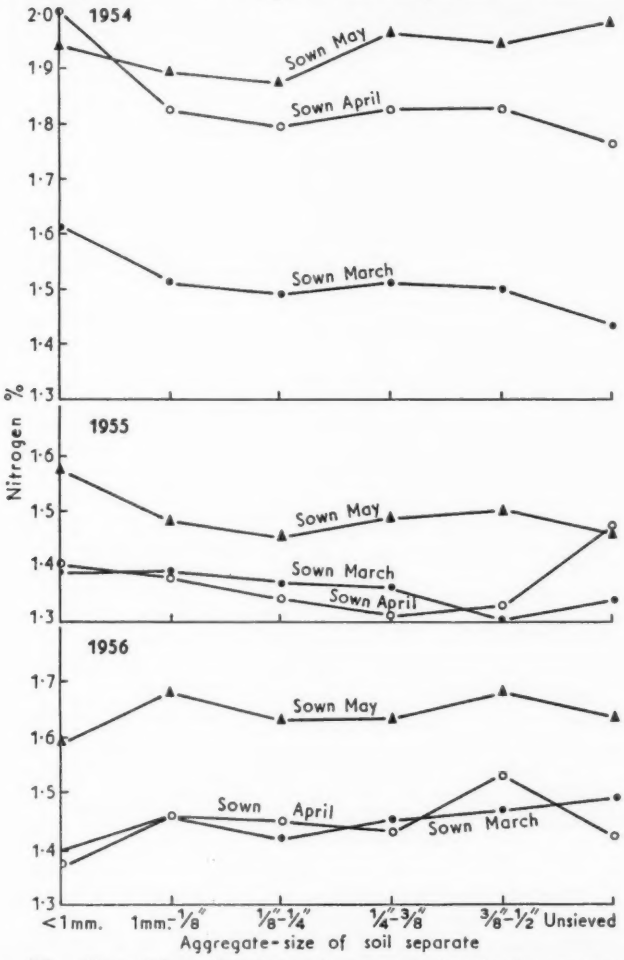

FIG. 5. The effect of time of sowing and aggregate-size of soil separate on the nitrogen content of Spratt Archer Barley grain 1954, 1955 and 1956. (Each point is the mean of 4 plots 1954 and 1955; of 2 plots 1956.)

beds to require higher uprooting tensions, but this reached significant levels only in the 1956 barley experiment. Sieved seed-beds other than the finest did not differ significantly from each other.

Table 19 shows that the tension required to uproot a plant was significantly higher on the consolidated seed-beds in the spring barley

TABLE 18. *Effect of Aggregate-Size of Soil Separate in the Seed-bed on the Tension required to Uproot S. 172 Winter Oats and Spratt Archer Barley at Harvest*

(*Means of* * *12 samples*, † *4 samples*, ‡ *12 samples*, § *6 samples*)

Aggregate-size of soil separate			< 1 *mm.*	1 *mm.*–$\frac{1}{8}$ *in.*	$\frac{1}{8}$–$\frac{1}{4}$ *in.*	$\frac{1}{4}$–$\frac{3}{8}$ *in.*	$\frac{3}{8}$–$\frac{1}{2}$ *in.*	*Unsieved*	*Least significant difference*	
									P = 0·01	P = 0·05
Tension to uproot in lb.	W. Oats	1954–5*	15·2	10·8	9·8	10·8	11·4	11·0	2·28	1·76
	W. Oats	1955–6†	17·8	11·7	13·8	11·9	10·7	13·5	5·90	4·20
	Barley	1954‡	8·4	7·2	6·6	6·1	6·4	6·7	0·83	0·64
	Barley	1956§	9·8	6·4	6·7	7·4	6·7	8·0	1·79	1·29

TABLE 19. *Effect of Consolidation of the Seed-bed on the Tension Required to Uproot S. 172 Winter Oats and Spratt Archer Barley at Harvest*

(*Means of* * *36 samples*, † *12 samples*, ‡ *36 samples*)

Seed-bed treatment			*Not consolidated*	*Consolidated*	*Least significant difference*	
					P = 0·01	P = 0·05
Tension to uproot in lb.	*W. Oats	1954–5	11·0	12·0	n.s.	n.s.
	†W. Oats	1955–6	13·1	13·4	n.s.	n.s.
	‡Barley	1954	6·5	7·3	0·47	..

experiment 1954. Differences in this character in the winter oats experiments were not significant but showed a similar trend. It is unfortunate, in this instance, that no data were obtainable from the other barley experiments.

Discussion and Conclusions

Some discussion of specific points in the data has been given during the presentation of the results. The discussion which follows is mostly on a more general plane.

The experiments were conducted on one soil type over a limited number of seasons, and the conclusions drawn must be viewed in relation to these facts. It should, further, be recognized that, because of the important effects of frost heaving on the winter oats, the yield data from the experiments on this cereal are less consistent than those from the barley experiments. The first general impression of the effects of the sieving treatment on yields is that the differences are surprisingly small. Although extreme differences in seed-bed conditions were obtained by the sieving process the plants were able to produce satisfactory yields, in most instances, on all grades. This implies that the cereals studied were not particularly sensitive to changes in the aggregate sizes in the seed-bed within the limits used. This negative conclusion is important in that it helps to explain why such small differences in the yield of cereals have been obtained in experiments where differential cultivations have been imposed [7, 8]. If barley plants can yield well in a seed-bed initially consisting very largely of clods and stones $\frac{3}{8}$–$\frac{1}{2}$ in. in diameter it is hardly surprising to find that, unless soil type and condition be very different from these, differential cultivations have produced but small

differences in yield. It may be observed that, in these experiments, differences in yield attributable to differences in the seed-beds are often outweighed by the effects of sowing date. There is no reason to suppose that the effect of applied nitrogen might not also outweigh the seed-bed differences, and this would appear to be worth testing.

Marked differences in yield of grain and straw which may be correctly ascribed to the seed-bed treatments have nevertheless emerged. Although the order of yielding capacity has not been by any means constant, it appears fair to say that the general result has been as follows:

The $<$ 1 mm. separate gave the highest yields (provided the effect of frost on winter oats be discounted). Unsieved soil gave the next best yields in general but was less consistent in its relative position. The coarsest seed-bed, $\frac{3}{8}$–$\frac{1}{2}$ in., was at least as good as, and often superior to, the other separates (excluding the finest). The 1 mm.–$\frac{1}{8}$ in. separate, the finest-but-one, was consistently poorer in yield than all the remainder. It is striking that no gradation of yields corresponding to the gradation in aggregate-size of soil separate has emerged. Obviously many other complex factors are involved. In an earlier paper [1] it was pointed out that the stoniness of this soil was a disturbing factor and that coarse plots were not only coarser but also stonier. If increasing stone content (and hence reduction in true soil volume per plot) played any considerable part in accounting for yield differences it might be expected that the $\frac{3}{8}$–$\frac{1}{2}$ in. separate would have given consistently lower yields than the others, but this is not so. The inferior yields found to be associated with the 1 mm.–$\frac{1}{8}$ in. separates were, at first, attributed to the redistribution of weed seeds (particularly of the seeds of *Stellaria media*) through sieving. This redistribution leads to a much higher population of weed seedlings in the 1 mm.–$\frac{1}{8}$ in. separates than in any other. Mann and Barnes [9] have shown that this chickweed is a most efficient competitor with barley. In spite of control measures by hand weeding it was felt that perhaps the early stages of infestation had a depressing effect on the yield from this separate. That weeds cannot be wholly, or indeed largely, responsible is shown by the 1956 results where weed competition had been virtually eliminated by spraying and yet the inferior yield of plants on the 1 mm.–$\frac{1}{8}$ in. separate was still evident. If, in the barley experiments, the yield and length of straw be examined in Tables 14 and 15 in relation to the behaviour of the 1 mm.–$\frac{1}{8}$ in. separate it will be seen that the inferiority of this size of seed-bed was greatest in the dry summer 1955 and least in the wettest summer 1954. This is a hint (and little more) that the low yields of this separate may be associated in some way with the water-supply to the plants. In this connexion it may be pertinent to point out that this separate contains substantially more coarse sand than any of the others. This was in fact the most striking redistribution of material below 2 mm. evident in the mechanical analyses of the soil separates given in Table 7 of the second paper of this series [2].

Other workers on the growth of plants on sieved seed-beds [10, 11, 12, 13] have found optimum yield on seed-beds other than the finest. Doiarenko (as reported by Krause [10]) working on a podsolized soil near Moscow found best yields on crumbs 1–2 mm. in diameter and

showed that particles $< 0{\cdot}5$ mm. were detrimental to cereal yield even in low concentration. Kvasnikov (as reported by Krause [10]) found the optimum yield of oats and wheat on seed-beds made up of crumbs between 2 and 3 mm. diameter. Hagin [11] found that yield was better on separates > 1 mm. than on smaller sizes. Yoder [12] obtained maximum yield of cotton on seed-beds made up of crumbs between $\frac{1}{8}$ and $\frac{1}{4}$ in. Schuylenborgh [13] working in Holland found that white mustard yielded best on a crumb soil and next best on clods 1–2 mm. but that clods < 1 mm. were superior to sizes > 2 mm. All these workers, however, were working on soils with a much higher content of silt and clay than that under consideration here. The inferior growth on very fine seed-beds has been mostly attributed to poor aeration and, by Hagin, to poor aeration and a concomitant depression of the rate of mobilization of nitrogen and phosphorus. The soil used in these Aberystwyth experiments has proved to be extremely resistant to puddling and the finest seed-bed remained permeable and without any serious surface crusting. The good yields obtained on the finest seed-beds imply that aeration must have been adequate. The behaviour of this soil would lead one to suppose that it has a much better crumb structure than the soils used by the workers cited above. It would be valuable to repeat these experiments on a heavy clay soil where interference from the larger particles would be much less and where seed-beds too fine for optimum growth might be produced.

The effect of the time-of-sowing treatment on yield is not comparable in oats and barley. In the former the indirect effect via damage by frost has overshadowed any other effects time of sowing may have had. In barley the picture is more straightforward. Early April sowings gave the highest yields and May sowings the lowest. Early March sowing appears to be too early in this district except in favourable seasons. Early sowing gave better-quality barley grain than late sowing both as regards increased size of grain and lower nitrogen content. The effect of seed-bed treatments on the latter character has been discussed already in the text.

The consolidation-of-the-seed-bed treatment appears to have had little effect on the yield of oats and no discernible effect whatever on the yield of barley.

Finally, the overall influence of variation in climatic conditions should be mentioned. This has been referred to several times in the text, where tentative explanations of certain phenomena have been advanced. It must be recognized, however, that the effect of rainfall, temperature, amount of sunshine, &c., are so complex that with the data available most of the relationships between these factors and the growth of the plants must be conjectural, and useful, not as proven observations in themselves, but as possible indicators towards further experimental work on this subject.

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OBSERVATIONS ON THE ERUPTION OF CENTRAL PERMANENT INCISOR TEETH IN SHEEP

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Summary

In the course of an investigation into the effect of breeding from Half-bred/Suffolk and Clun/Suffolk cross ewe lambs on their subsequent growth, development, and performance, a study has been made of the change from primary to permanent dentition in respect of the central pair of incisor teeth. Observations were made on sixteen lambs born in 1953 and first mated as shearlings, and also on a similar number of lambs born in 1954 and first mated as ewe lambs, both groups being tupped for the first time in autumn 1954. It was found that the age of the latter at the time when eruption of the central pair of permanent teeth was complete was greater: by 4 weeks in the case of the Half-bred/Suffolk lambs and by 2 weeks in the Clun/Suffolk lambs. This was primarily due to the longer period which elapsed between the loss of the first temporary incisors and the complete eruption of the permanent incisors. Since the period coincided with lactation it is considered that milk secretion, rather than pregnancy, had most significance in the determination of the age at which completion of this change in dentition occurred.

In the unmated lambs the average age at completed eruption was 3 weeks greater for the Clun/Suffolk crosses compared with the Half-bred/Suffolk crosses. The progress which the lambs had made to weaning, measured by weaning weight per day of age, was found to be significantly correlated with their subsequent age at eruption.

THE effect of breeding from ewe lambs in their first year of life on their growth and performance has been the subject of investigation on the Leeds University Farm since 1950. An aspect to which particular attention has been paid is the eruption of the central permanent incisor teeth. It was considered that the period covering the change from temporary to permanent dentition might be of significance in relation to the nutrition of such lambs at this critical stage. Accordingly a comparison has been made of the changes in dentition of two groups of lambs, one group being bred from and the other remaining unmated.

Little factual information on dental changes would appear to be available in the literature on sheep husbandry. Fraser [1] represents the views of most authorities in saying that the two primary incisors become loose and fall out between 10 and 14 months of age. The 'milk' incisors are replaced by two much longer and broader permanent incisor teeth, and by the time the latter are fully erupted the age of the sheep may vary from 1 to 1½ years. The Smithfield regulations lay down that sheep having their central incisors cut will be considered as exceeding 10 months. That there is wide variation between individuals is, however, fully recognized. Various authorities state that time of birth, general health and vigour of the individual, and plane of nutrition are all causes of variation. Youatt [2] gives the general impression that lambs reared on a high plane of nutrition renew their teeth earlier in life than those reared on a low plane. Coop and Clarke [3] investigated the influence of the method of

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rearing hoggets on the lifetime productivity of ewes, and observed the teeth of ewes at regular intervals. Hoggets reared on a low plane by being maintained on a variety of bare pastures and an occasional spell on turnips lost their milk teeth earlier than another batch grazed on good pasture. On the other hand, at 2 years old the 'high-plane' ewes were more advanced in respect of the number of teeth erupted than the 'low-plane' ewes. The earlier difference is probably related to the spell of turnip feeding. Franklin [4], studying the overall requirements of sheep in Australia, similarly expresses the view that a low plane of nutrition resulted in delay of eruption. Breed has significance according to Miller [5]—in the improved breeds teeth erupt much sooner than in coarser-bred half-wild varieties—and he gives the average eruption age for the former as 12–15 months for the first pair of permanent teeth and 21 months for the second pair. More recently Wiener and Purser [6] have shown that replacement of deciduous teeth by permanent is affected both by the level of nutrition during the preceding seven months and also by breed. Working with sheep derived from Blackface ewes by crossing with Wiltshire, Border Leicester, Lincoln, and Blackface rams, and from Welsh ewes mated with Welsh, Wiltshire, and Suffolk rams, they found that the better the feeding the earlier was the replacement of the milk by permanent incisors, while the proportion of permanent teeth erupted at the time of examination was greater in the Wiltshire crosses than in their contemporaries.

No evidence is available concerning the effect of early pregnancy and lactation on the eruption of permanent teeth. Palsson [7] investigated the various effects of early pregnancy in Icelandic sheep and found that skeletal growth was retarded slightly by pregnancy and rather more by the ensuing lactation. It would seem logical to assume that early breeding would have some effect on teeth formation particularly under conditions of low nutrition. A questionnaire circulated by one of the authors in 1953 among farmers with Half-bred flocks revealed the impression that breeding from lambs had a deleterious effect on their life in the breeding flock and the commonest cause of culling is usually taken to be the loss of incisor teeth in old age. It was also concluded by Coop and Clark [3] that longevity of the ewes was reduced as a result of low-plane rearing as hoggets. They suggested that a deleterious effect on tooth structure or hardness was revealed by subsequent greater wear, probably from abrasion, though not excluding other possibilities.

Sheep Used in the Investigation

The sheep used in the investigation were bred on the University Farm, where the main flock in 1953 consisted of Scottish Half-bred and Clun Forest ewes being crossed with Suffolk rams for fat-lamb production. From the lamb crop in that year were retained sixteen Half-bred/Suffolk cross ewe lambs and sixteen Clun/Suffolk cross ewe lambs, each born a twin, with the exception of one single. The thirty-two lambs were reared and eventually mated, as shearlings, with a Hampshire ram in October 1954. Therefore, during the period when incisor teeth changes

were being recorded these lambs were unmated and were not affected by pregnancy or lactation. This group will be referred to as UM lambs.

From the 1954 lamb crop, a similar group of thirty-two lambs was retained, as far as possible each being a twin and a full sister to one of the lambs kept from the previous year. In the outcome twenty lambs were thus selected, the other twelve being twin lambs born from ewes with a similar breeding record to the dams of the unpaired 1953-born lambs, the birth weights of the lambs being similar. This group of 1954 lambs was mated to the same Hampshire ram in November 1954. They will be referred to as LB (lamb-bred) lambs. Essentially therefore, sixty-four individuals composed of sixteen pairs of Half-bred/Suffolk crosses and sixteen pairs of Clun/Suffolk crosses were first mated to a Hampshire shearling ram in autumn 1954, one of each pair being a shearling and the other a lamb.

The LB lambs were born slightly earlier in 1954 than the corresponding UM lambs in 1953, by about one week on average. Both groups were well reared by their dams and were weaned at an average liveweight of about 90 lb. Following weaning, in each year the lambs were treated with phenothiazine and were kept on leys through the summer. Feeding during the winters was fairly similar for both groups, but the pregnant lambs were put on a higher plane of nutrition as lambing approached.

TABLE 1. *Comparative Data for UM and LB Lambs*

	Half-bred/Suffolk		*Clun/Suffolk*	
	UM	*LB*	*UM*	*LB*
Birth weight (lb.) .	11·8	11·8	10·6	10·8
Age at weaning (days) .	94·2	97·7	104·4	99·4
Wt. at weaning (lb.) .	89·6	91·9	88·6	91·1
Wt. per day of age at weaning (lb.) . .	0·95	0·95	0·86	0·93
Wt. in November (lb.) .	133·5	141·4	129·2	137·1
Wt. in March (lb.) .	144·9	172·2	140·0	158·0

Sugar-beet tops, either carted on to a ley or folded, was the main food until January when kale was gradually substituted for the tops. For short periods in January and April 1954, however, the UM lambs received fodder beet, and in 1955 the LB lambs received mangolds for a short time during March and April. A concentrate ration consisting of 95 per cent. crushed oats and 5 per cent. fish meal was fed to the pregnant lambs for two months before lambing, at a rate of ½ lb. rising to 1 lb. per head per day. A comparison of the two groups of lambs is given in Table 1.

At the time they were turned to the ram the LB lambs were rather better grown than the UM lambs at the corresponding November weighing. The subsequent slower rate of gain of the UM lambs reflects the general pattern of growth of lambs in late winter, whereas the pregnant lambs gained substantially.

The LB group started lambing on 23 March 1955 and ended on 10 May. Good results were obtained and are summarized in Table 2.

Method used to Record Eruption of Teeth

All lambs were weighed at regular intervals from the time they were weaned, every two weeks in the case of the UM lambs, weekly in the case of the LB lambs. Inspection of teeth commenced at the beginning of April for the former, in March for the latter, and at each collection for weighing a record was made of the losses in milk teeth and the replacement of these by the permanent incisors. On inspection a note was made

TABLE 2. *Lambing Results from LB Lambs Mated in November 1954*

	Half-bred/Suffolk	*Clun/Suffolk*
No. put to ram . .	16	15
No. which lambed . .	14	15
No. barren . . .	2	nil
No. which lambed singles	6	9
No. which lambed twins .	8	6
No. lambs born . .	22	21
No. lambs reared . .	20	17

of the presence or absence of each of the two central temporary incisors and the state of eruption, if any, of their permanent replacements. Thus it was possible to estimate the period required for the central permanent incisors to become fully erupted and the age of each lamb at the completion of eruption. Records were made only in respect of the two central temporary and permanent incisors, and in computing the relative data for each lamb the mean of the figures for individual teeth was taken.

Results

Loss of Milk Teeth

Loss of the temporary teeth of the UM lambs occurred in most cases in May, as shown in Table 3.

TABLE 3. *Incidence of Loss of Temporary Teeth—UM Lambs*

Period	*No. of lambs*	
	Half-bred/Suffolk	*Clun/Suffolk*
Before 5 April 1954	4	1
5 April–3 May .	2	2
4 May–31 May .	6	8
1 June–28 June .	2	1
29 June–14 July .	..	2

Table 4 gives the incidence of loss for the LB lambs.

The pattern of distribution is quite similar in the two groups. In the LB lambs loss of the first temporary incisor occurred before lambing in three cases only and on average 5–6 weeks elapsed between the date of lambing and the date when the first milk incisor loss was recorded.

Eruption of the Permanent Incisor Teeth

The effect of breed and lambing on the age of lambs at the time of complete eruption of the first pair of permanent incisor teeth is shown

in Table 5 together with the levels of the statistical significance of the differences. The data are based on records from fifty-six sheep, fourteen in each subgroup, the four subgroups being regarded as treatment combinations for the purposes of analysis.

TABLE 4. *Incidence of Loss of Temporary Teeth—LB Lambs*

Period	*No. of lambs*	
	Half-bred/Suffolk	*Clun/Suffolk*
Before 1 April .	..	1
1 April–30 April .	2	1
1 May–31 May .	13	7
1 June–30 June .	1	4
1 July–31 July .	..	1

TABLE 5. *Age of Lambs at time of Eruption of first Pair of Permanent Incisor Teeth (weeks)*

	Half-bred/Suffolk (HBS)	*Clun/Suffolk (CS)*	*Mean*	
Maiden lambs (UM)	62·0	65·2	63·5	CS > HBS†
Bred lambs (LB) .	66·2	67·0	66·6	n.s.
Mean . . .	64·1	66·1	65·1	n.s.
	LB > UM‡	LB > UM*		LB > UM‡

* Significant at P = 0·05 level.
† ,, ,, ,, 0·01 ,,
‡ ,, ,, ,, 0·001 ,,

Breeding from the ewe lambs increased the age at which their permanent incisor teeth erupted, the difference being more marked in the Half-bred/Suffolk crosses than in the Clun/Suffolk crosses. There was also a significant difference due to breed in the UM lambs, the Half-bred/Suffolk crosses completing eruption three weeks earlier on average than the Clun/Suffolk crosses.

Period of Eruption

The time taken for the permanent incisors to become fully erupted following the loss of the temporary incisors was not capable of very rigid definition, but approximate figures were obtained for fifty-two sheep, analysis of the results being based on four subgroups with thirteen in each. Results are given in Table 6.

On average the lambs which had been bred from showed an increase of one week in the time required for the permanent incisors to become erupted. This was true of both sets of cross-breds and there was no difference due to breed.

In Tables 5 and 6 the figures are derived from the averages for pairs of teeth. By taking the period of dental change from the time of the first recorded loss of a temporary incisor to the time of complete eruption of the second central permanent incisor greater differences between the UM and LB lambs become apparent; see Table 7.

TABLE 6. *Length of Period Required for the Eruption of the first Pair of Permanent Incisors (weeks)*

	Half-bred/Suffolk	*Clun/Suffolk*	*Mean*
Maiden lambs (UM).	2·7	3·0	2·8 n.s.
Bred lambs (LB) .	3·7	4·0	3·8 n.s.
Mean . . .	3·2	3·5	3·3 n.s.
	n.s.	n.s.	LB > UM*

* Significant at P = 0·05 level.

TABLE 7. *Length of Period covering Change in Dentition (weeks)*

	Half-bred/Suffolk	*Clun/Suffolk*
UM lambs .	4	4½
LB lambs .	7½	7½

Age at Eruption in Relation to Liveweight Gain

Examination of the individual data for the UM lambs showed a tendency for the better-grown lambs to complete eruption of the permanent incisors at an earlier age. Correlations were accordingly calculated between age at eruption and rates of growth to weaning, from weaning to November, and from November to March. The highest correlation ($r = -0.37$) was found with weight per day of age at weaning and was significant at the $P = 0.05$ level. The correlations with subsequent gains in weight were insignificant.

Discussion

The results indicate that breeding from ewe lambs leads to delay in the time of eruption of the first pair of permanent incisors. This is mainly due to a lengthening in the period required for the permanent incisors to replace the temporary milk teeth, and in consequence the overall period of the change in dentition of the central incisors is longer. From the design of the experiment, it will be realized that the change in dentition occurred in different years, with some differences in feeding in the respective winter periods, and further work is necessary to establish the variation from year to year which might follow different nutritional environments. However, the high level of nutrition afforded to both these groups of lambs and the fact that incidence of temporary incisor loss was similar in both years are considered to justify ascribing the delay in eruption mainly to factors concerned with reproduction.

According to Franklin [4] permanent incisor eruption is closely linked with the efficiency of calcium and phosphorus utilization and there is no evidence to suggest that this is impaired by the condition of pregnancy. More significant is the coincidence of the growth of the permanent incisors with the period of suckling, when a greater drain on the mineral supply of the dam might be expected. It is probable that this was the main cause of the greater age at eruption of the lamb-bred group compared with the unmated lambs, following the slower rate of eruption of

the permanent teeth. The practical significance would seem to be that yearling ewes with lambs at foot should have access to food which is easily ingested and when lambing occurs in April, with grass available, no difficulty should arise. However, it may be a contributory reason for the lower productivity of lamb-bred ewes with their first lamb crop compared with that of ewes bred first as shearlings, as is normal practice.

The difference in age at eruption between the two crosses in the UM group is difficult to interpret save on genetic grounds and supports the view of Wiener and Purser that there is some genetic control of the time of eruption of the permanent incisors. It may be an expression of slightly later maturity of the Clun parent breed compared with the Half-bred. Table 5 illustrates the slower growth to weaning of the Clun/Suffolk crosses and in view of the correlation established between growth to weaning and age at eruption, the breed difference may be due to this. The fact that there was little difference between breeds in the LB group may be due to a greater effect of lambing and suckling on the Half-bred crosses than on the Clun crosses. Whereas the difference in age at eruption between UM and LB Half-bred/Suffolks was 4·2 weeks on average, it was only 1·8 weeks for the Clun/Suffolks. This may be a result of the greater productivity of the former, which produced heavier lambs at birth, reared more twins, and ultimately produced a greater amount of lamb carcass. It could be expected that greater milk production would have a more pronounced delaying effect on the time of eruption of the incisor teeth.

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CENTROSEMA PUBESCENS: GROUND COVER AND FORAGE CROP IN CLEARED RAIN FOREST IN GHANA

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Summary

Yields of *Centrosema pubescens* were recorded at a cleared Forest Station in Ghana over a 2-year period. Vegetative analyses and a field estimate of yield are given.

Data are presented to indicate its carrying capacity in terms of Dwarf Forest sheep, which are native to this region of West Africa.

It is concluded that persistence of Centrosema in areas where grazing is practised depends on the stocking intensity.

Calopogonium muconoides is the most aggressive volunteer species at Asuansi and in certain areas dominates the more palatable Centrosema.

The shallow-rooting habit, and conditions suitable for the production of seed, are discussed. It is emphasized that there is a relationship between yield and rainfall, and that Centrosema is likely to succeed only where the pattern of rainfall is favourable. Chemical composition data are presented. There was no great seasonal variation.

Digestion coefficients obtained with West African Dwarf Forest sheep are presented. Crude fibre was relatively indigestible.

The nutritive value of Centrosema, as calculated from the digestion coefficients, is high: starch equivalent 10, digestible crude protein 3·2, nutritive ratio 3:1.

SOIL exhaustion in the humid tropics can be very rapid, assuming a speed which in the first account may be directly related to the scale of man's interference with the virgin-forest canopy.

Like many other humid tropical forest zones, much of the original high rain forest of Ghana has been exploited to an extent and at a rate which exceeds the regenerative capacity of the valuable hardwoods which have been extracted. The position in Ghana is further aggravated by continuing pressure of population which automatically creates a need for more food crops. The introduction of cacao at the beginning of the century and its development as a major forest-tree crop has also played a considerable part in the destruction of the under, middle, and to some extent the over canopy of much of the original forest.

Evidence of soil exhaustion may be noted in cleared or partially cleared areas, where a shifting pattern of food crop farming is now practised. This form of farming, dictated by need to rest the soil and build up fertility, would seem to be wasteful in terms of land, and has the effect of permanently destroying one of the nation's principal capital assets, its regenerating forests.

In the tropics, denudation of cover in areas which receive an annual precipitation of 50 in. of rain and over, must always be a hazardous operation, although this is conditioned by the distribution and pattern of rainfall. The planting of light-demanding tree crops, such as oranges and grapefruit, in such situations, calls not only for soil-protection treatment after clearing, but also for careful consideration of the equally important aspect of soil fertility maintenance.

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Use of leguminous crops for ground cover and fertility building has been practised in tropical as well as temperate zones for a long time. It was only towards the middle of the nineteenth century, however, that the association of leguminous plants and soil nitrogen was recognized.

A leguminous crop has particular value in the humid tropics when it supplies anti-erosion cover, nitrogen, and biological humus to the soil. The latter has special significance in improving the physical structure of certain soils, plays a role in the conservation of soil moisture, and acts as a bank for the main store of nitrogen in the soil.

Centrosema pubescens Benth. was introduced to Ghana in 1926 by the Department of Agriculture (J. D. Broatch, private communication). Seed was sent initially for sowing, observation, and trial to Asuansi, a partially cleared Forest station 20 miles inland from Cape Coast. There was need for a suitable species to supply ground cover and to fulfil some of the requirements outlined above. Centrosema was reputed to meet some of these requirements, particularly in respect of undercover for plantings of citrus, rubber, and other tree crops grown in humid Tropical Forest Zones. At a later stage the forage value of the species was examined [1].

It has been argued that green cover crops cannot perform two functions together, namely to provide nutrient for small ruminant animals such as sheep and goats, and at the same time to act as soil conserver and supplier of plant nutrient for a principal orchard or forest crop. Much would depend, it seems, on the intensity of stocking and the amount of cover removed and returned in digested form to a particular area of land by the grazing animal. Few records are available of what such demands and returns might be in practice.

Whatever may be the ideal biotic association and balance, there can be no doubt that effectively nodulated Centrosema with its near-independence of soil nitrogen supplies, and its ability to produce apparently fair yields of green forage of high protein value, would seem to deserve more attention and increasing interest as a medium for maintaining fertility, and as a provider of valuable animal fodder in the humid tropics of West Africa.

The present account deals with agronomic field studies, chemical analyses, and digestibility investigations which have been carried out during the past three years at Asuansi and at the University College of Ghana.

Agronomic Investigations

Material and Methods

Yield sampling. In a citrus grove planted and undersown with Centrosema, five plots were randomly selected and enclosed against grazing animals. Cutting and weighing took place approximately at monthly intervals on a 2-square-yard sample area within each plot. At each cut a 3-in. stubble was left to counteract possible yield-depression effects due to over-defoliation. Fresh samples were weighed *in situ*. A representative bulk sample from all plots was sealed in airtight jars

for analytical purposes. In 1955–6 a fresh series of plots was randomly selected again in the same citrus grove.

The soil and soil sampling. The plots were sited on a fairly uniform sandy loam soil which contained fragments of varying size of unweathered Cape Coast granite, the underlying rock. Soil depth varied, but averaged 20 in. above the unweathered rock surface. A soil sample was qualitatively examined from each plot along with a sample from an adjacent area which had no Centrosema cover. Sampling was carried out to a depth of 8 in. on the plot diagonals. pH was determined electrometrically using a soil/water ratio of 1:5. Phosphorus was estimated colorimetrically by an ammonium molybdate stannous chloride method, in an extract made with 2·5 per cent. acetic acid. Potassium, calcium, and sodium were determined by flame photometer. A titian-yellow method was used for magnesium estimation.

Vegetation analysis. Samples of Centrosema were taken from three randomly selected areas adjacent to the enclosed plots. Clipping removed all top cover to soil-surface level, care being taken to avoid mixing stoloniferous parts and trailing surface vines. Soil was carefully dug out from square-foot sample areas to collect the root systems, tap roots being followed to their maximum depth. All soils were sieved, the roots and other vegetative parts being stored immediately in sealed Kilner jars. Analysis was carried out within 24 hours, subsampling being performed as quickly as possible to avoid loss of weight.

Botanical analysis. Observations were made in this series on the occurrence of volunteer species which show signs of becoming established. No point-quadrat analysis was attempted. Earlier analysis carried out by Mr. D. Westwood, of the Ghana Department of Agriculture, and Professor A. S. Boughey, late of the University College of Ghana, indicate a few of the more aggressive species which might be expected to gain some ground at the expense of Centrosema.

Meteorological data. Temperature and rainfall data for Asuansi are given in Table 1.

Results and Discussion

Growth potential of Centrosema. Data in Table 2 exhibit considerable yield variation between successive samples.

Yield may be markedly influenced by plant nutrient status of the soil, and daily temperature and rainfall. Mean daily temperature showed little fluctuation throughout the year (Table 1) while of the remaining factors, rainfall only fluctuated from month to month. It is reasonable to expect a fairly close relationship between rainfall and yield. Assuming an absorption time-lag of from 2 to 4 weeks after the fall of good rains, a connexion may be noted (Tables 1 and 2). These data also reveal a carry-over effect from one rainy month to subsequent drier months. It is not possible, however, from the data available to predict with any accuracy the effect on yield from each additional inch of rain above the average for any given period during the year.

TABLE 1. *Meteorological Data—Asuansi (342 ft. above sea-level)*

Temperature: Monthly means of average maximum and minimum thermometer readings (°F.)
Rainfall: Monthly totals (in.)

Months	1954		1955		1956	
	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall
January . .	77·6	0·26	77·7	6·17	78·1	0·20
February . .	79·0	2·19	79·5	0·03	79·4	1·47
March . .	79·4	6·23	79·0	5·58	78·4	8·70
April . .	79·1	7·31	79·1	5·39	80·9	6·52
May . . .	75·0	8·25	78·7	5·55	78·1	8·39
June . . .	75·9	8·91	76·2	13·90	75·7	10·31
July . . .	73·1	2·57	74·2	4·02	73·6	0·62
August . .	73·1	1·64	74·0	2·14	73·2	0·96
September . .	75·2	3·98	75·8	2·86	75·8	3·00
October . .	76·2	11·28	77·1	6·53	77·1	8·12
November . .	77·9	5·83	77·4	4·77	77·5	3·14
December . .	77·8	2·65	76·8	2·64	77·5	2·85
Annual mean .	76·6	..	77·1	..	77·1	..
Annual Total .	..	61·10	..	59·58	..	54·28

TABLE 2. *Centrosema Plot Yields—Asuansi (means for five 2-sq.-yd. plots)*

Date of sampling (day–month)	Interval since last sampling (days)	Mean yield per plot (oz.)	Confidence limits (P = 0·05)
	Plot Series No. 1		±
1954			
6–4	35	24·2	5·8
30–6	85	23·4	8·9
29–7	29	16·2	2·8
2–9	35	11·4	5·5
28–9	26	8·9	2·04
2–11	35	24·9	5·2
2–12	30	5·2	4·08
1955			
2–2	62	19·1	4·7
12–3	38	5·4	2·3
	Plot Series No. 2		
1955			
9–6	27	3·5	1·58
21–7	42	25·8	6·54
20–8	30	3·1	1·64
22–9	33	6·0	3·94
26–10	34	20·5	6·82
30–11	35	18·1	2·89
1956			
4–1	35	5·3	1·54
1–2	28	0·6	0·65
9–3	37	8·5	2·82
20–4	42	12·8	3·82
18–5	28	8·4	4·39

TABLE 3. *Estimate of Yield per Acre (cwt.)*

	Highest	*Lowest*
Plot Series No. 1 1954–5 . .	245	137
Plot Series No. 2 1955–6 . .	187	96
Mean	216	116

A 'field estimate' of yield per acre is offered (Table 3), based on the statistical significance of the mean plot yields in Table 2. Having regard to the danger of basing conclusions on such figures, obtained by multiplying small plot yields, these estimates must be regarded merely as a guide. In this connexion yields of Centrosema grown in the particular forest setting may be compared with the average of a series of green grass yields (two cuts) in 1954–6 from natural pasture in a drier but apparently equally infertile habitat (rainfall 26 in.) at Nungua, the University College's Agricultural Research Station on the Accra Plains. These showed annual yields of 125 and 52 cwt. green grass per acre, with and without fertilizer (ammonium sulphate 3 cwt., single superphosphate 1 cwt., per acre) (F. Hagenzieker, unpublished data). The yield potential of Centrosema in relation to these figures appears to have some importance in view of the apparently poor plant-nutrient status of most of the Forest soils in Ghana.

The soil nutrient status. The nutrient status of the Asuansi plot series (Table 4) compares unfavourably in some respects with figures presented by de Endredy and Montgomery [2] for a range of fifty-one undisturbed Forest soils in Ghana:

TABLE 4. *Analysis of Soil of Plot Site compared with the Mean of Fifty-One Forest Soils*

Description	*Soil type*	*pH*	*Acetic-acid-soluble* P *mg./100 g.*	*Exchangeable ions M.equiv./100 g.*			
				K	Ca	Mg	Na
Asuansi Centrosema cover for 10 years (mean of five plots)	Free-draining sandy loam	6·4	1·9	0·10	3·96	0·64	0·09
Mean of 51 Forest soils [2]		5–6	..	0·40	6·15	..	0·1–0·4

The mean figure for phosphorus is within the range of eleven Forest soils overlying granitic gneiss examined by Nye and Bertheux (unpublished data). From the agronomic standpoint the significance of the nutrient figures for these soils lies in their apparent ability to support yields of up to 11 tons of green material per acre per annum. The effect of fertilizer applications was not studied in these investigations, but seems worthy of future consideration particularly in respect of applications of phosphorus.

Growth habit and vegetative analysis. Like other creeping legumes, Centrosema displays to the casual observer some lack of definition between the root systems on the one hand and the soil-surface fractions, the creeping stolons, on the other. Table 5 indicates the breakdown of the plant into its morphological components. Given time and no other competition, a single plant may cover an extensive area of ground.

TABLE 5. Centrosema pubescens—*Morphological Analysis, Asuansi 1956. Mean of Three Samples expressed as gm. per sq. ft.*

Description of components	*Mean*	*Confidence limits* (P = 0·05)	*Percentage of whole*
Aerial components			
Green palmate leaflets	52·5	±7·55	25·8
Green vines, leaf petioles, and upright shoots	43·0	±2·00	21·1
Root and soil-surface systems			
Primary (tap system and rhizomatous roots)	53·0	±2·59	26·1
Secondary (adventitious roots)	21·3	±4·91	10·5
Surface (surface and sub-surface stolons)	26·2	±16·48	12·8
Total viable components	196·0	±16·56	96·3
Dead leaves and trash	7·5	±3·27	3·7
Total all components	203·5	±14·42	100·0

The aerial portions of the plant contributed approximately 47 per cent. towards the total weight; the root and soil-surface systems provided almost all of the remainder.

Sheep show interest in the palmate leaflets, leaf petioles, upright shoots, and part only of the trailing vine system, which tends to become woody with age. If left freedom of choice it would appear that they would consume only 70 per cent. of the green aerial components.

The main root system of Centrosema at Asuansi was predominantly shallow, never penetrating much deeper than 2 in. below the surface. The occurrence of nodules on the secondary root system appeared also to vary considerably. Examination of several sample areas indicated a development of approximately two tap roots per square foot. Some of these were followed to their maximum depth, which was found to be 18 in., but the average is possibly nearer 12 in. The shallow-rooting habit of Centrosema must explain in part the inability of the species to make satisfactory growth in 'one-peak' rainfall areas which experience very dry conditions for several months after the peak rains are over. The transpiration rate and water loss from an area of Centrosema seems likely to be high.

Observations in other parts of Ghana suggest that Centrosema will grow satisfactorily only in 'twin-peak' rainfall areas which receive a minimum of 40 in. of rainfall per annum. In High Rain Forest (70–100 in. rainfall) Centrosema grows luxuriantly and may in fact become

a menace to other species. It may sometimes be growing 30–40 ft. above ground level, using boles of trees and lianes for support.

The plant is most successfully propagated by seed (about 18,000 per lb.) which can be sown in rows 3 to 4 ft. apart at the rate of 3 lb. of seed per acre. The rows soon fill in and give complete ground cover in 4 to 6 months.

Centrosema does not set seed readily at ground level, but if allowed to climb over a trellis or fence produces seed readily during the drier seasons of the year. At Nungua fence-supported Centrosema gave an estimated pod yield of forty-eight per square yard, yielding twenty seeds per pod, or approximately 1,000 seeds per square yard. On this basis one picking from 50 square yards would supply all the seed necessary to sow one acre.

The persistence of Centrosema. The particular circumstances at Asuansi, with sheep grazing as part of the system of husbandry, introduce a factor which probably has some effect on the persistence of Centrosema as ground cover. The incidence of grazing must obviously upset the normal successional effect, palatable species being depressed at the expense of non-palatable species. There is also visual evidence that severe defoliation, which includes overgrazing, impairs subsequent growth of Centrosema, although mechanical defoliation seemed much harsher in its effect than grazing defoliation.

A list of volunteer species was recorded in November 1955 inside and outside the enclosed observation areas at Asuansi. Some were notably grazed or browsed, some were more frequent than others (Table 6).

At an earlier period (1948–51) Mr. D. Westwood [3] and Professor A. S. Boughey made an analysis of a series of plots which had been set aside for a sheep-grazing and feeding trial. The following list of volunteer species were noted by them as prominent in varying degree:

Achyranthus aspera
Ageratum conyzoides
Aspelis latifolia
Boerhaavia sp.
Calopogonium sp.
Cyathula prostrata
Cyperus rotundus
Digitaria horizontalis
Mariscus umbellatus
Momordica charantia
Paspalum conjugatum
Setaria barbata
Setaria longiseta
Synedrella nudiflora

In the authors' opinion the volunteer species showing greatest aggressiveness is *Calopogonium muconoides*, which shows obvious signs of spreading at Asuansi. In certain areas it is already dominant. Unfortunately this hirsute species is not attractive or palatable to sheep in its natural state and therefore gains at the expense of the more palatable Centrosema.

Some areas sown with Centrosema ten to fifteen years ago have had to be ploughed up and resown. Sheep grazing, however, need not necessarily lead to deterioration. With intelligent management the life of a Centrosema cover and forage crop need not be less than ten years, and it may last much longer. Everything would seem to depend on the grazing intensity. If grazing does not occur the life of Centrosema pastures is not necessarily lengthened. This may be accounted for by

TABLE 6. *Volunteer Species in Centrosema Areas*

Species	*Frequency*		*Palatability*
	Enclosed area	*Open area*	
Achyranthus aspera Linn. . . .	I	I	U
Justicia flava Vahl.	F	I	P
Ageratum conyzoides Linn. . . .	I	I	..
Bryophyllum pinnatum Olsen . .	A	F	U
Melanthera scandens Schum. and Thom.	I	I	P
Calopogonium muconoides Desv. . .	A	F	U
Digitaria velutiana P. Beauv. . .	I	I	P
Oplismenus burmanii P. Beauv. . .	I	I	U
Setaria longiseta P. Beauv. . . .	I	F	U

A = absent I = infrequent F = frequent U = unpalatable P = palatable.

the inhibiting effect of the accumulation of trash (dead leaves, &c.) which deters fresh growth.

Utilization of Centrosema. The sheep at Asuansi are of the West African Dwarf Forest type. Adult ewes weigh only about 38 lb. at maturity, rams may be 50–60 lb. Two-and-a-half-year-old wethers have been fed up to liveweights of 80 lb., while one-and-a-half-year-old wethers weigh from 40 to 50 lb.

The sheep flock as a whole is divided into two ewe flocks, one ram and wether flock, and one ewe lamb/gimmer flock. These flocks are grazed separately and rotationally over the various Centrosema-sown pastures and other Centrosema-invaded open ground pastures, which amount in total to approximately 100 acres.

At Asuansi the stock of sheep of all classes amounts at any one time to approximately 550. The average stocking intensity on these Centrosema pastures is therefore 5·5 per acre. These figures are somewhat misleading as some of the more productive Centrosema areas are more intensively grazed than others. The sheep are grazed on the pastures from 8 to 11 a.m. and again from 3 to 6 p.m. This time-table avoids the dew-laden (and therefore helminth-dangerous) early hours and the mid-day heat.

Dwarf Forest sheep are thrifty and make fair to good progress under these forest conditions, but the danger of helminthiasis is always present, particularly amongst the younger animals. Anthelmintic dosing is carried out regularly at Asuansi with copper/nicotine sulphate.

Given reasonably dry weather conditions Centrosema may be dried into useful hay, but like most pure legume hays it tends to shatter and drop leaf if handled too frequently. Hay is fed at Asuansi when sheep remain housed, such as during periods of very heavy rainfall when the pastures are waterlogged and conditions are impossible for grazing.

Two groups of wether lambs under trial (1948–50) gained an average of 14·7 lb. in liveweight per sheep over 11 months, from 25·9 lb. to 40·6 lb. Having regard to their small natural size this gain is fairly satisfactory from unassisted Centrosema grazing.

There is some evidence from Asuansi that Centrosema in itself may

be too protein-rich even for young growing stock (Table 7) and that supplementation of their grazing with starchy cassava root (manioc) may have beneficial effects. Unfortunately the report quoted [4] does not indicate the quantity fed, the duration of the trial, or the economic implications of feeding this supplement.

TABLE 7. *Grazing Trial—Cassava Supplementation* [4]

	No. of wethers in each group	*Liveweight increase (lb.) Centrosema only*	*Confidence limits (P = 0·05)*	*Liveweight increase (lb.) Centrosema plus cassava*	*Confidence limits (P = 0·05)*
Trial I .	5	12·8	±3·90	15·6	±0·36
Trial II .	8	9·4	±3·49	12·5	±4·0

Supplementary raw cassava root is consumed with avidity by these Forest sheep on Centrosema plots at Mankessim. This is an outstation (about 5 miles from Saltpond, which has an annual 'two-peak' rainfall distribution of approximately 48 in.), where the possibility of establishing Centrosema pastures has been convincingly demonstrated. The small-scale pastures, natural fencing materials used, and the modest number of sheep required, are all within the scope and reach of the smallest Ghana farmer.

Chemical Composition and Nutritive Value

Although Centrosema has been fairly widely grown on West African experimental stations as a cover crop or fodder crop, alone or in mixtures, not a great deal is known about its nutritive value. Limited data on its chemical composition are available for Centrosema grown in other parts of the world.

Since data from only one set of digestion trials for fresh Centrosema, carried out in the Philippines, were available [8], digestion trials were carried out.

Methods and Analytical Technique

Field sampling was as described on p. 352.

Laboratory sampling and storage. On arrival at the laboratory the samples were divided into two equal portions and weighed at once before being dried. The oven-dried material (105° C. for 5 hours) was ground in a Christy Norris mill, using a 1-mm. sieve, and stored in screw-cap bottles. Because of the high relative humidity, and the difficulty of making the caps airtight, all samples were redried and placed in calcium chloride desiccators immediately before analysis.

Analytical. Crude protein was estimated, as total nitrogen (N) × 6·25, by the Kjeldahl process. Fat was estimated by extracting 16 hours with petroleum ether. Crude fibre was estimated on the residue by the Weende method. Ash was determined by ignition at 550° C. Nitrogen-free extract, N.F.E. (soluble carbohydrate), was determined by difference. Calcium was estimated by the oxalate permanganate method, potassium by flame photometer, and phosphorus colorimetrically as vanadate.

Digestion trials. The input and output of the various constituents were measured over a period of 14 days, and the digested constituents, estimated by difference, expressed as digestion coefficients.

Type of sheep. West African Dwarf Forest sheep were used. These were all wethers weighing from 25 to 40 lb.

Digestion cages. Harnessless cages were designed to hold pairs of sheep, having a floor of expanded metal and chicken wire, below which was a screen of fine-mesh copper mosquito gauze to retain the faeces pellets while allowing urine to pass through. Some food material tended to fall on to the faeces screen. This was sorted out at frequent intervals by an attendant and returned to the feed box. Five such cages were used, housing ten sheep in all.

Feeding. Centrosema was collected by hand at Asuansi and Pokoase Agricultural Stations.

It was not considered possible to harvest only the fraction normally selected by sheep. The whole plant excluding coarse surface runners and underground parts was harvested. From the difference in weight and composition of the total material offered to the sheep and rejected material, the composition of the consumed material was estimated. The rejected material was mostly stems. The dry-matter contents of leaves and stems of the somewhat wilted material offered were not greatly different, except in the case of a few rather mature, woody stems and runners inadvertently included in the sample. The mean dry-matter percentage of the Centrosema offered was therefore used to calculate the weight of fresh material rejected and hence the actual intake of fresh material. Where wider differences between stems and leaves occurred, for instance with very fresh, succulent material, it was possible to obtain an approximate figure for the dry-matter percentage of the rejected material at the time of feeding by measuring the dry matter of the stems, which constituted most of the rejected portion.

Feed routine. The sheep were fed three times daily. A preliminary feeding period established the approximate appetite of the sheep by feeding the Centrosema at diminishing levels until no residual leafy material was left in the troughs. Rations at this level were weighed out daily into polythene bags and samples taken for dry matter and chemical analysis.

Digestion trial procedure. After a preliminary feeding period of 10 days the collection period began. Faeces and rejected material were collected daily before the morning feed, weighed and sampled for analysis.

Results and Discussion

Chemical composition of monthly samples. From the data in Table 8 it is clear that there was little seasonal variation in composition during the year apart from the dry-matter content which is at its highest in the hot, dry-season months. There is also some evidence that the crude protein content of Centrosema is at its lowest during the hot, dry months of January to May, which is to be expected in view of the slower rate of growth at this time.

No studies were made in Ghana on the effect of stage of growth on

chemical composition. Guayadeen [9] examined Centrosema at 6, 9, and 12 weeks in Trinidad, Oyenuga (unpublished data) examined Centrosema at 0–25 weeks and 17–40 in. in Nigeria. The variation found with age and height at cutting was no greater than the seasonal variation shown in Table 8.

TABLE 8. *Chemical Composition of Monthly Samples*

(Dry matter: % on fresh weight. Other figures: % on dry matter)

Date	*Dry matter*	*Crude protein*	*Ether extract*	*Crude fibre*	*N.F.E.*	*Ash*	P	K	Ca
2.12.54	28·0	23·7	2·3	25·8	41·0	7·3	0·24	1·65	1·56
1.1.55	No sample								
2.2.55	38·5	19·7	2·9	27·6	44·4	5·4	0·19	1·45	1·21
12.3.55	33·5	17·4	2·4	29·6	45·3	5·4	0·18	1·13	1·56
14.4.55	22·7	18·6	3·2	30·5	41·9	5·7	0·22	1·45	1·35
13.5.55	26·0	17·0	2·4	32·0	42·5	6·0	0·15	1·43	1·21
11.6.55	18·8	21·1	1·7	26·0	44·6	6·7	0·24	2·05	1·09
21.7.55	21·6	19·2	2·0	32·3	41·1	5·4	0·20	1·68	1·15
20.8.55	23·4	19·4	2·4	30·6	41·8	5·8	0·22	1·55	1·42
22.9.55	22·9	23·6	1·5	33·3	35·0	6·6	0·25	1·68	1·56
26.10.55	23·9	21·1	1·9	31·1	38·6	7·3	0·22	1·58	1·29
30.11.55	21·6	20·0	2·4	38·1	33·5	6·1	0·20	1·60	1·35
12.55	No sample								
1.1.56	23·8	19·0	2·8	32·0	41·4	6·7	0·18	1·60	1·50
Mean .	25·4	20·0	2·3	30·0	40·9	6·2	0·21	1·58	1·35

The mean chemical composition of the twelve monthly samples of Centrosema conforms closely to figures obtained elsewhere, and in Table 9 is compared with analytical data from Malaya, Australia, the Philippines, and Trinidad, including some other widely grown legumes.

TABLE 9. *Comparing the Chemical Composition of* Centrosema pubescens *from Asuansi with some other widely grown Legumes and* Centrosema pubescens *from other continents*

	Crude protein	*Ether extract*	*N-free extract*	*Crude fibre*	*Ash*	P_2O_5	K_2O	CaO	*Author*
Centrosema (Asuansi, Ghana)	20·0	2·3	40·9	30·0	6·2	0·47	1·47	1·76	
Young Red Clover	25·5	3·6	42·8	18·4	8·0	0·75	2·50	2·00	Woodman [5] and Kellner [6]
Red Clover (beginning to flower)	17·8	3·7	42·6	27·3					
Lucerne (before bud)	25·3	2·7	38·0	22·0	12·0	0·87	3·20	3·00	Woodman [5]
Lucerne (in bud)	24·5	2·3	40·9	28·2	8·2	0·70	2·80	3·85	Woodman [5]
Centrosema (Australia) .	18·7	3·0	38·4	30·3	9·6	0·8	..	2·5	Schofield [7]
Centrosema (Philippines) .	20·0	4·8	31·2	33·0	8·0	..	..	..	Reyes [8]
Centrosema (Trinidad) .	25·5	..	..	26·5	..	1·7	..	1·0	Guayadeen [9]
Centrosema (Malaya) . .	21·6	2·4	34·0	30·0	9·2	0·44	..	0·8	Gunn [10]

Digestion trials. One of the features of the digestion trial results shown in Table 10 is the close agreement between the pairs of sheep. A notable exception in the case of ether extract is probably due in part to the large error involved in the laboratory determination but may also be due to the fact that some fat is excreted with the faeces and hence a low and variable 'apparent' digestion coefficient can be obtained.

TABLE 10. *Digestion Coefficients* (%)

Constituent	*Pair 1*	*Pair 2*	*Pair 3*	*Pair 4*	*Pair 5*	*Mean*
Dry matter . . .	52·7	54·4	55·2	52·6	52·4	53·5
Organic matter . .	52·0	54·0	55·0	53·0	52·0	53·2
Crude protein . .	61·5	60·9	62·0	62·3	64·7	62·4
Ether extract . .	42·0	45·0	36·0	47·6	51·1	44·3
N-free extract . .	62·9	61·3	64·2	60·7	57·6	61·3
Crude fibre . .	37·0	42·0	40·1	39·1	39·1	39·5
Ash	55·0	57·3	58·1	55·0	54·8	56·0

A second feature is the very low digestion coefficient for crude fibre which indicates that these Forest sheep were not able to deal very effectively with that fraction since, in general, green legume crude fibre may be expected to have a digestion coefficient of the order of 60 per cent. Gunn Lai Teik [10] has estimated the digestion coefficient of Malayan-grown Centrosema crude fibre at about 60 per cent. but he did not carry out digestion trials. Reyes [8] in the Philippines, on the other hand, carried out digestion trials on Centrosema with sheep and goats, obtaining digestion coefficients for crude fibre of the order of 35 per cent., which is in line with the results in Table 10.

Nutritive value of Centrosema. The nutritive value of Centrosema expressed in starch equivalents (Kellner) and digestible crude protein is compared in Table 11 with some other widely grown green legumes and with Centrosema grown in the Philippines. It can be seen that the nutritive value is high.

TABLE 11. *Comparing the Nutritive Value of Centrosema with some other widely grown Legumes*

	Starch equivalent	*Digestible crude protein*	*Nutritive ratio*	*Author*
Centrosema (Asuansi, Ghana) .	10·0	3·2	1:3	
Red Clover (young) . .	10·0	3·4	1:3	Kellner [6]
Red Clover (beginning to flower)	10·2	2·5	1:4	Woodman [5]
Lucerne (before bud) . .	9·0	4·3	1:2	Woodman [5]
Lucerne (in bud) . .	11·3	3·6	1:3	Woodman [5]
Centrosema (Philippines) .	8·8	3·2	1:2·14	Reyes [8]

The calculated nutritive value refers to the Centrosema actually consumed, so that when estimating yields of starch equivalent per acre, it is important that the percentage of plant material, as harvested and

offered, which is rejected by the sheep, should be taken into account. In these trials about 21 per cent. of the dry matter harvested was rejected by the feeding sheep. The rejected portion was entirely stems and runners.

On this basis the yield of Centrosema, in terms of nutritive value per acre, could be estimated from the fresh-weight yield data of Table 3 and would be of the order of 12 cwt. of starch equivalent and 4 cwt. of digestible crude protein.

Dry-matter intake. During the preliminary feeding period a number of observations were made on the dry-matter intake of the Forest sheep and a figure of 3 per cent. of the body weight was taken for the daily appetite. There was, however, considerable variation between pairs, with a range of 2·6 to 3·2 and a mean of 2·9. These appetite figures are for sheep kept under abnormal conditions and though they may provide a useful guide, they are unlikely to be exact.

Conclusions

The annual yield of Centrosema in cleared High Forest zones in Ghana appears to compare well with the yield of pasture grass in areas which naturally support a grassy vegetative cover.

Establishment and development call for a well-distributed minimum annual rainfall of not less than 40 in. per annum. Precipitation in excess of 60 in. annually gives rise to luxuriant development with competitive encroachment on other vegetation.

Centrosema does not appear to be particularly demanding in plant nutrients and at Asuansi flourishes on forest soils which are below average in this respect.

When acclimatized, sheep acquire a taste for the species and make fair progress under admittedly trying climatic conditions. On the other hand, there is evidence that even for younger animals, the species, with a nutritive ratio of only 1:3, supplies an excess of protein. Addition of some starchy supplement gives evidence of beneficial effects in terms of liveweight increase, but the small natural size of West African Forest sheep lends doubt to the economy of such a practice. Quite apart from its value for grazing, Centrosema with its very high content of digestible protein is clearly a valuable crop for all branches of animal nutrition, whether as a green roughage, hay, or even a dried meal.

Based on accepted dry-matter-intake levels, Centrosema pastures in settings such as Asuansi are potentially capable of supporting a substantial number of sheep per acre, were it not for the dangers of parasitic disease and the inability of the species to stand up to intensive prolonged grazing. Numbers have therefore to be geared to the reality of these biotic influences.

On a small-farm scale in West Africa, the use of Centrosema in an alternate-husbandry approach for the restoration of fertility in degraded forest country, with animal protein as one of the products, seems to be worthy of serious consideration and extended trial in contrats to the more normal practice of long-term bush fallowing.

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THE EFFECT OF ETHYLENE DICHLORIDE AND CARBON TETRACHLORIDE ON THE GERMINATION AND EARLY GROWTH OF MAIZE

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Summary

Trials with five varieties of maize and different concentrations of a fumigant consisting of equal parts by volume of carbon tetrachloride and ethylene dichloride have shown that prolonged storage of grain with the fumigant may affect seedling growth. The varieties differ in susceptibility and the emergence of a root or shoot from the grain gives no indication of the subsequent vigour of the plant.

Evidence is presented which suggests that ethylene dichloride might, however, possibly be safe as a fumigant if the storage temperature were lower than that usually prevailing in the tropics.

THE practice of using a mixture of ethylene dichloride and carbon tetrachloride as a grain fumigant is widespread [1, 2, 3], particularly in underdeveloped countries where the low toxicity to man and ease of handling make such a fumigant preferable to others which may be more effective.

Though this fumigant may appear to have little effect on the germination of maize when the emergence from the grain of the radicle or plumule is taken as the criterion of viability, it usually has a profound effect on the subsequent growth of seedlings. In this paper an account is given of some experiments designed to investigate the effect of the fumigant on the early growth of maize seedlings.

The susceptibility of five different maize varieties to a fumigant consisting of equal parts by volume of ethylene dichloride and carbon tetrachloride has been tested. The effect of temperature on the susceptibility of one variety has also been studied.

A 1:1 mixture of ethylene dichloride and carbon tetrachloride has been found to be more satisfactory under local conditions than the usual 3:1 mixture. The results presented below for the 1:1 mixture are similar to those obtained previously with the 3:1 mixture.[1]

Materials and Methods

For the fumigation of seed grain on the University Farm it is the practice to use 10 c.c. of fumigant per cubic foot of storage space, after which the container is sealed until the grain is needed for planting.

[1] When these earlier results were published [4] it was incorrectly stated that the fumigant was a mixture of ethylene dichloride and carbon bisulphide (instead of carbon tetrachloride).

[Empire Journ. of Exper. Agric., Vol. 26, No. 104, 1958.]

In experiment 1, described below, five varieties of grain were exposed to three different concentrations of fumigant for periods of up to four months. The varieties used were Lagos White, Agege Tsolo, a bulked Trinidad variety referred to as '3795 Trinidad', Mexico 1, and Cuba Amarillo × Mexico 16 × Sicaragua × Mexico 16 ('triple cross'). The grain, which was dried to an average moisture content of 12·8 per cent., was placed in 500-gm. lots in 2-lb. jars with airtight lids. After adding the appropriate amount of fumigant from a burette, each jar was instantly sealed and shaken. The jars were kept in a laboratory in which the temperature ranged between 80° and 90° F. The fumigant was prepared by mixing standard laboratory carbon tetrachloride and ethylene dichloride. It was applied at three levels of concentration: 10, 20, and 40 c.c. per cubic foot. For each variety of maize there were three controls and three replicates of each treatment.

At the end of the storage period the jars were unsealed. Half the grain was poured out and a sample taken from the middle of the jar. From each jar fifty grains were tested for viability on damp blotting paper and ten grains were planted in garden soil in an 8-in. pot. The viability tests lasted a week, after which it was assumed that no further germination would occur. Seedlings which germinated in the pots were measured daily for ten days commencing on the fifth day after planting. All the leaves of each plant were drawn up vertically and the height was measured from the soil to the tip of the highest leaf.

Experiment 2 was designed to determine the effects of ethylene dichloride and carbon tetrachloride used separately and whether they were unsatisfactory only when used together. A further aim was to determine whether there was any marked interaction between temperature and the effect of the fumigant. The maize variety Mexico 1 was chosen as it is widely planted locally and is known to be damaged by fumigation with the mixture.

Using the same general procedure as in experiment 1, each of the fumigants alone and a 1 : 1 mixture of the two were tested at the laboratory temperature (82°–94° F.) and in a cool-store (70°–84° F.). There were four replicates of each treatment and the control, giving eighty jars in all, forty at each temperature.

The grain was air-dried to a moisture content of about 11 per cent. The storage period was three months, after which ten seeds were removed and planted in pots. After ten days the heights of the emerged seedlings were measured to the nearest half-centimetre.

Results

Experiment 1

The results given are for storage over a period of four months, but reference will also be made to the results of storage for shorter periods.

Germination tests. The total numbers of seeds which had germinated by the end of seven days are shown in Table 1. From this table it is evident that the fumigant as applied has a differential effect on the germination of the varieties tested.

TABLE 1. *Germination of Maize Varieties Treated with Different Concentrations of Fumigant**

Maize variety	*Concentration of fumigant (c.c./cu. ft.)*			
	0	*10*	*20*	*40*
Lagos White	141	144	138	134
Tsolo	127	134	129	125
Trinidad	145	128*	131*	116*
Mexico 1	125	115	117	106*
Triple cross	141	142	137	132

* The number of seeds germinating in a sample of 150 after four months storage in different concentrations of the fumigant. Those values against which there is an asterisk differ significantly (P = 0·05) from their control value.

Growth studies. The data on growth studies are too extensive to quote in full, but are summarized in Fig. 1 and Table 2. In Fig. 1 the daily results for the variety Mexico 1 are presented in graphical form; the results for the other varieties followed the same pattern.

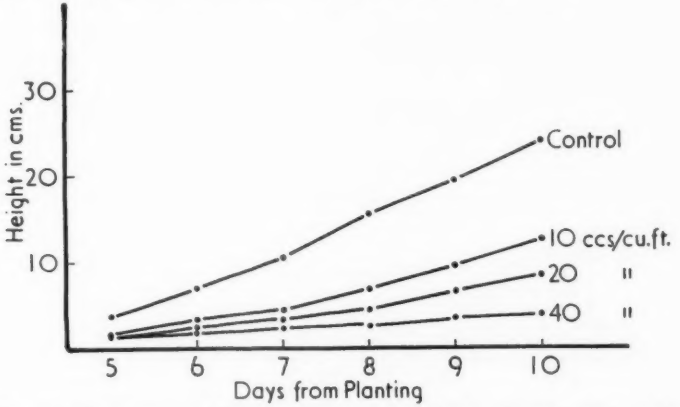

FIG. 1. The mean seedling heights of maize (Mexico 1) grown from grain treated with different concentrations of fumigant.

TABLE 2. *Mean Seedling Heights in cm. of Certain Maize Varieties Ten Days after Planting*

Maize variety	*Concentration of fumigant (c.c./cu. ft.)*			
	0	*10*	*20*	*40*
Lagos White	30·4	24·6	8·0	1·4
Tsolo	26·7	23·6	11·5	2·3
Trinidad	27·6	18·9	3·6	1·3
Mexico 1	24·0	12·7	8·5	4·0
Triple cross	24·0	19·2	21·3	11·1

The mean heights of each variety at the end of ten days are shown in Table 2, from which it is evident that in each instance the fumigant

retarded the growth of the treated seedlings and that the amount of retardation was roughly proportional to the concentration of fumigant used.

Experiment 2

A summary of the results with the pooled data from the replicates is presented in Table 3.

TABLE 3. *Mean Plant Height* (m) *in cm. Ten Days from Sowing for the Maize Variety Mexico 1* (n *is the number of plants measured*)

Treatment (*c.c./cu. ft.*)	*Storage temperature*					
	82–94° F.			*70–84° F.*		
	n	m	S.E.	n	m	S.E.
Control	34	17·6	±0·4	38	18·3	±0·4
CCl_4 10	35	16·8	±0·7	39	17·5	±0·5
CCl_4 20	34	16·5	±0·5	39	17·5	±0·4
CCl_4 40	37	17·9	±0·4	36	17·7	±0·4
$(CH_2)_2Cl_2$ 10	35	13·3	±1·2	36	14·0	±1·2
$(CH_2)_2Cl_2$ 20	32	11·6	±1·4	36	14·8	±1·2
$(CH_2)_2Cl_2$ 40	38	10·9	±1·2	31	11·1	±1·4
Mixture 10	37	14·4	±1·2	37	17·3	±0·7
Mixture 20	37	15·5	±1·1	35	16·3	±0·8
Mixture 40	37	11·1	±1·4	35	12·3	±1·3

Discussion of Results

Experiment 1

Perhaps the most interesting observation that arises from the foregoing results is that, although the percentage germination of the grain of a given variety of maize may not be significantly affected by the fumigant, the growth of seedlings arising from the grain was usually subnormal. This observation is very important as it is often assumed that a fumigant is safe if it does not adversely affect germination, accepting the emergence of the radicle or plumule as an index of germination.

Though it is not evident from the results as presented, the damage to the grain is of two kinds; the growth of seedlings derived from the grain is either generally depressed or may cease altogether when the plant is only 1 to 2 cm. above the ground. Leaves of plants showing this more profound effect may not open, and the plant may finally die without further growth. That the proportion of stunted plants obtained from treated grain depends on the concentration of fumigant to which the grain was subjected is shown in Table 4. Severely stunted plants were not produced from grain which had been fumigated for less than a month, indicating that the effect depends on the duration of exposure to the fumigant.

TABLE 4. *Percentage of Seedlings that failed to attain a Height of 3 or more cm. within Ten Days of Planting*

Maize variety	*Concentration of fumigant (c.c./cu. ft.)*			
	0	*10*	*20*	*40*
Lagos White	0	7	19	100
Tsolo	0	0	8	92
Trinidad	0	0	60	100
Mexico 1	0	12	12	77
Triple cross	0	14	8	31

It is clear that the fumigant affected different varieties to differing extents, and it is interesting to note that the seedlings obtained from a three-way cross were by far the least affected both in terms of growth depression and the proportion of severely stunted plants produced.

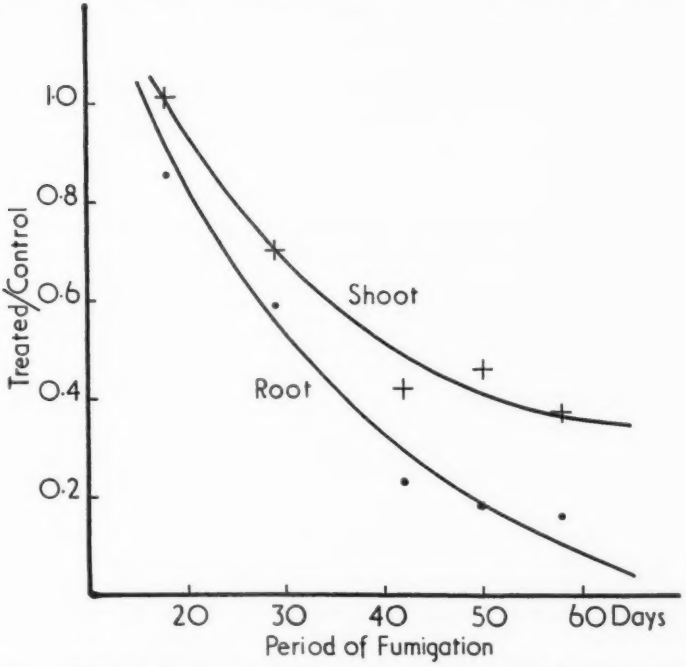

FIG. 2. Effect of different fumigation periods on the root and shoot development of maize.

Besides the concentration of fumigant, the period of fumigation is also important in determining the amount of growth depression likely to be shown by seedlings derived from fumigated seed. This has been investigated in some detail for the variety Mexico 1 with the results presented in Fig. 2.

In this figure the growth depression was measured by expressing the fresh weights of the roots and shoots of seedlings from treated grain as a fraction of their untreated controls. It is interesting that the growth of the shoot was less affected by the fumigant than that of the root.

A comparison of the seedling heights from grain that had been aired for several days before planting with those of seedlings from grain

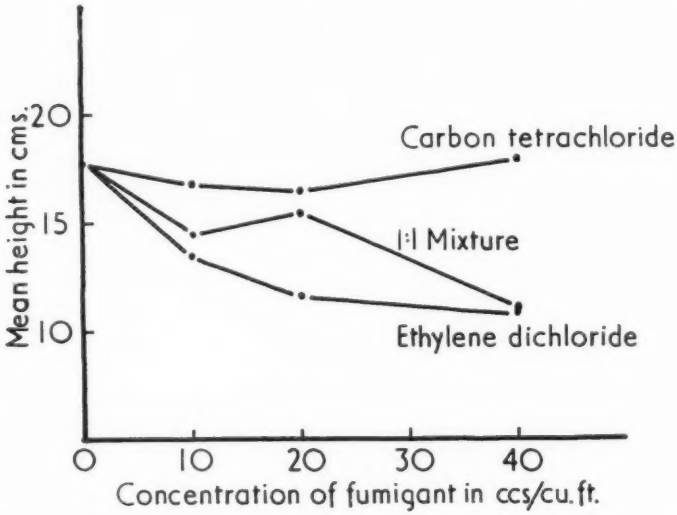

FIG. 3. Mean seedling height of maize grown from grain treated with two fumigants alone or in combination, at room temperature.

planted out directly from the fumigant showed that no benefit resulted from such airing. The nature of the damage to the maize embryo as a result of fumigation has not been studied in detail but the morphology of the shoot apex of retarded and normal seedlings appeared to be similar.

Experiment 2

It is clear from Table 3 that any one of the three fumigants caused the early growth of maize to be retarded relative to that of the control.

Fumigation with carbon tetrachloride had the least effect and seedlings from grain so treated were only slightly smaller than their controls at the end of the experiment. No individual difference between the control and any given concentration of fumigant was significant at the $P = 0{\cdot}05$ level, but for five of the six comparisons the seedlings from the grain fumigated with carbon tetrachloride were smaller than their controls.

Fumigation with either ethylene dichloride alone or in admixture with carbon tetrachloride markedly affected the growth of seedlings from treated grain. There appeared to be little interaction in the effect

resulting from using the mixture. As shown in Fig. 3, the graph for the 1:1 mixture is intermediate between those for ethylene dichloride and carbon tetrachloride.

A comparison of the results for grain stored at different temperatures showed that there were no significant differences ($P = 0{\cdot}05$) for the early growth of the control seedlings and those from grain fumigated with carbon tetrachloride, though with one exception the growth was better from grain that had been stored at the lower temperature.

However, the effect of storage temperature on the subsequent growth of fumigated grain was sometimes quite marked when ethylene dichloride or the 1:1 mixture had been used as fumigant. In each of the six comparisons the growth of seedlings from grain stored at the lower temperature was better than that for seedlings from grain stored at the higher temperature and two of these differences in growth were significant at the $P = 0{\cdot}05$ level.

The results for germination have not been analysed in detail but it is evident from Table 3 that storage temperature has not markedly affected germination as measured by the number of plants that emerged from the soil, though the percentage germination so measured was slightly higher following storage at the lower temperature.

General Discussion

The conditions of fumigation in Ibadan whereby the grain has been stored with the fumigant in sealed bins for up to periods of a few months may not be typical. However, it had been found to be satisfactory for several years, mostly with the variety Tsolo. This variety has now been shown to be only slightly susceptible to the fumigant at the usual rate of application.

It is evident that fumigation of maize grain with a mixture of ethylene dichloride and carbon tetrachloride may impair its ability to produce healthy plants, though it may not affect the capacity of the grain to germinate. In the literature there are few references [5] to the growth of plants from fumigated seed and little attention appears to have been given to this topic.

Had attention been given to growth studies as well as to germination it is unlikely that ethylene dichloride–carbon tetrachloride mixtures would have been so unreservedly recommended for the fumigation of seed maize in the tropics. However, it may be quite satisfactory under temperate conditions, for the results of experiment 2 suggest that storage temperature is an important factor in determining whether seed grain may be stored in contact with the fumigant for long periods.

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THE RESPONSE OF ELEUSINE TO DIFFERENT FORMS OF NITROGEN FERTILIZER

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Summary

The question of the forms of nitrogen applied to annual crops and the yields resulting therefrom is a problem of increasing importance. A short review of the relevant literature is given with some indication of the special position of Eleusine as the staple cereal in south-west Sudan, from the viewpoints of soil, agronomy, and nutrition.

A preliminary experiment with Eleusine on a dark sandy loam was laid down. Two forms of nitrogen were applied, as sodium nitrate and ammonium sulphate, at two different levels. The yield data revealed a definite result that only the ammonium sulphate was effective, at the level of 80 lb. N per acre with an increase in yield of about 40 per cent. over that obtained with sodium nitrate.

THE forms in which nitrogen is applied to annual crops and the yields resulting therefrom have been problems of increasing interest to investigators in the post-war period. Although plants normally absorb their nitrogen in the form of nitrates certain plants would appear to prefer ammonium salts. Among these are some crops of economic importance such as potatoes and swamp rice. Allison [1] has shown that higher plants are able to use nitrogen in this form, often with great facility. It has been pointed out that young plants of almost all kinds are particularly capable in this respect, although they seem to grow better if some nitrate nitrogen is also available.

In general, plants can take up their nitrogen requirement either as ammonium or nitrate ions, and it is thought that in most cases they can utilize either with equal facility. In the case of certain cereals, and whatever the explanation, there are grounds for thinking that ammonium ions provide more readily available nitrogen to the growing plant in the early stages than do nitrate ions. From the results of a preliminary experiment this would seem to be the case with Eleusine (*Eleusine coracana* Gaertn.). But our understanding of this mechanism today is just as meagre as that of processes whereby micro-organisms can produce nitrate in the soil solution.

Russell [2] has summarized our present knowledge of the problem. He points out that the main difference between these two ions is that all the nitrate in the soil is dissolved in the soil solution whilst, if the soil contains much clay or humus, much of the ammonium will be present as an exchangeable cation and hence not in solution. For this reason a nitrate fertilizer could be expected to act more rapidly than an ammonium salt since it would be present in higher ionic concentration round the root system of the plant. In general, so far as most arable soils are concerned, added ammonium ions are fairly soon oxidized to nitrate. It follows that no matter what form of nitrogen is applied, nitrate is

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usually the only form present in appreciable concentration in the soil solution available for plant nutrition. Consequently in temperate and tropical regions the fluctuating nitrate status of the soil has received most attention.

In the course of an investigation of nitrate accumulation in Uganda soils, extending over several years, Griffith and Mills [3] found no appreciable difference in crop yield when nitrogen was applied to Eleusine at the rate of 100 lb. per acre whether in the form of ammonium sulphate or as sodium nitrate. The application of kraal manure at 10 tons per acre more than doubled the yield obtained with either of these two fertilizers. The authors rightly concluded that their findings posed more problems than they solved.

A comparison of the results of experiments on the forms in which nitrogen fertilizers were applied to spring cereals has been the subject of a recent investigation at Rothamsted. In two experiments on barley and one on wheat, Widdowson *et al.* [4] compared the results of combine-drilling and broadcasting of both ammonium sulphate and calcium nitrate at equal rates of nitrogen per acre. It was found that calcium nitrate gave slightly higher yields than ammonium sulphate when the fertilizers were broadcast; there was little difference when they were drilled. In the two barley experiments combine-drilling gave consistently higher yields than broadcasting when ammonium sulphate was used; with calcium nitrate broadcasting was slightly superior. In the wheat experiment broadcasting of either fertilizer gave higher yields than combine-drilling.

Experience in the Sudan with irrigated cotton on the heavy alkaline clays of the Gezira is noteworthy. Because of soil conditions Crowther [5] found ammonium sulphate to be a less efficient source of nitrogen than calcium nitrate and concluded that about 20 lb. of the nitrogen added as ammonium sulphate seemed to be lost when it was used as a top-dressing. But, as Russell suggests [6], from indirect evidence it would probably be as effective as the nitrate had it been drilled instead of being broadcast. Urea is the chief fertilizer used on the Gezira cotton crop today.

A forms-of-nitrogen experiment has been carried out by Anthony and Ogborn [7], on cotton, on an alkaline silty clay loam at Giar Farm in the Abyan area of the Aden Protectorate. Four forms of nitrogen fertilizer, viz. aqueous ammonia, ammonium sulphate (21·2 per cent. N), calcium nitrate (11·9 per cent. N), and urea (46·7 per cent. N), were placed at a depth of 6 in., 1 ft. distant from the plants. Two rates of application of nitrogen were used at two different dates. The results revealed no significant differences in response between the four forms of nitrogen applied. These findings are in conformity with Sudan Gezira experience.

Forms and Amount of Nitrogen in Precipitation

A significant but variable source of ammonium and nitrate nitrogen, frequently disregarded, is provided in the precipitation reaching the soil in different regions of the earth. Nitrogen occurring in rain and snow is

generally found in the forms of ammonia and nitrate and consequently is readily available to the growing plant. Although the amounts of nitrogen thus added to the soil are very variable, it is known that these additions are greater in the tropics than in humid-temperate regions and larger in the latter than in semi-arid climates.

Lyon *et al.* [8] have compiled relevant data of the amounts of nitrogen brought down in precipitation, which indicate that the ammonium nitrogen thus added to the soil is, in temperate regions at least, always larger in amount than that in the form of nitrate. It is also evident that, while the nitrate nitrogen is roughly the same in amount for most localities, the ammonium nitrogen reveals wide fluctuations. From these data the important conclusion is drawn that under humid-temperate climates an average of about 4½ lb. of ammonium and 1½ lb. of nitrate nitrogen fall on every acre of land annually in precipitation. Allowing for loss in run-off these authors conclude that an equivalent of about 5 lb. nitrogen per acre per annum, in readily available forms, provides an important contribution to the nitrogen economy in the maintenance of soil fertility.

Eleusine coracana *Gaertn.*

Eleusine, or finger millet, known as *telabun* in Arabic and *moru* in Zande, is the staple cereal of Zandeland, south-west Equatoria, southern Sudan. It flourishes under conditions of comparatively high rainfall too wet for the production of dura. The plant can grow to a height of 4 ft., dependent on soil conditions, although 3 ft. is more usual. It has flattish stems and a digitate inflorescence producing four to sixteen ears roughly 2 to 4 in. in length. It produces small, round, buff-coloured grain. Although fairly tolerant of thin soils it yields heavily on good free-draining loams. Most of the varieties grown in south-west Sudan mature in 3 to 4 months. It is sown broadcast on tilled land following groundnuts and is usually intersown with sesame and sometimes with hyptis (*Hyptis spicigera* Lam.) and maize. The grain stores exceptionally well and, apart from its conversion into flour, is used as the basis for brewing native beer. Average yields of the order of ½ ton per acre can be expected, although wide variations have been recorded [9].

The explanation of the good storing qualities of Eleusine lies in the fact that the grain is too small for the larval stages of the main insect pests to be passed inside a single grain [12]. It is noteworthy that Eleusine has a special value in nutrition by reason of its high content of available calcium compared with other cereals and cassava. In view of the fact that the soils of south-west Sudan are very deficient in calcium (the exchangeable calcium status varies between 2 and 6 milliequivalents per cent.), it is remarkable that Eleusine can exhibit such a high concentration of this nutrient in the grain. The 'mining' capacity of this cereal for calcium must be considerable. In a region subject to the ravages of tsetse fly, which at present renders animal husbandry impracticable, Eleusine represents the major source of calcium supply in the diet of the peasantry.

Field Experiment

The present trial was intended to be the forerunner of more extensive field experiments extending over several seasons and including different treatments and elaborations. Although circumstances rendered this impossible at Yambio it was decided to put on record the results already obtained so as to provide a basis for further investigation.

A field experiment with Eleusine was laid out in order to compare two levels of nitrate nitrogen, applied as sodium nitrate, and two levels of ammonium nitrogen as ammonium sulphate. The fertilizers were applied at the rates of 40 and 80 rotls nitrogen per feddan,[1] with a control. The crop was sown in July, following the local practice of a broadcasting Eleusine after groundnuts, and the fertilizers were applied broadcast prior to sowing. The plot size was 100 sq. m. harvested and there were six replications in randomized blocks. The experiment was sited on second-year land which had been under cotton in 1953–4, on a level plot. The stand averaged 15–20 cm. between plants and the period from sowing to maturity averaged 120 days.

The soil was dark brown and sandy with occasional pea iron gravel and humic matter. It contained numerous live roots, fine and coarse, going deep down. The approximately 9 in. of top-soil overlaid a B horizon of red-brown sandy clay with a greater concentration of pea iron gravel, together with some quartz and weathering rock fragments. A composite sample taken to a depth of 6 in. had the following analysis:

Analysis of Top-soil

Colour (Munsell number)	3/2
Stones and gravel .	28 per cent.
Fine Soil	
Coarse sand . .	26 per cent.
Fine sand . .	48 ,,
Silt . .	6·5 ,,
Clay . .	19·5 ,,
pH (water suspension)	6·3
Total nitrogen (N) .	889 p.p.m.
Organic carbon (C) .	1·04 per cent.
C/N ratio . .	11·5
Exchangeable Ca .	3·2 m.equiv. per cent.

Analysis was carried out on the air-dry 2-mm. sample. The size of the fractions in the mechanical analysis are according to the International Scale.

The responses to the different treatments are summarized in Table 1.

Discussion

Of the two forms of nitrogen applied, only the ammonium sulphate was effective at the level of 80 r.p.f. nitrogen, and the data would appear to justify the conclusion that under these conditions Eleusine is a cereal

[1] Rotls per feddan (r.p.f.) = 0·95 lb. per acre = 1·07 kg. per hectare.

which prefers its nitrogen requirement in the form of ammonium salt. This finding has a direct bearing on the form and quantity of organic manuring best suited to this crop and such information will be of use in formulating a future nitrogenous fertilizer programme.

TABLE 1. *Yields with Different Forms of Nitrogen at Two Levels*

Treatment	*r.p.f. grain*	*per cent.*
Control	1,031	100
Sodium nitrate at 40 r.p.f. N. .	1,158	112
,, ,, at 80 r.p.f. N. .	1,142	111
Ammonium sulphate at 40 r.p.f. N.	1,257	122
,, ,, at 80 r.p.f. N.	1,622	157
Significant difference P = 0·05 .	375	

Coefficient of variation = 25·2 per cent.

Sodium nitrate was used as the source of nitrate ion because of its availability at the Station. In view of the well-known effects of this fertilizer on the reaction, structure, and tilth of the soil it might have been preferable to use calcium nitrate. In an experiment extending over twelve years at the State Agricultural Station, Groningen, Holland, on a sandy peat soil of pH 5·5, a treatment of calcium nitrate did not affect the pH while sodium nitrate raised it by 0·3 and ammonium sulphate lowered it by almost 1 unit [10]. Possibly similar effects could be expected on the sandy loam used in the Yambio trial. Perhaps a temporary raising of the pH, as a result of the sodium nitrate treatment in the Yambio experiment, may have had the effect of rendering other essential nutrients in the soil solution partly or wholly unavailable to the plant. Should this be the case it postulates the existence of other unknown limiting factors.

The role of sulphur remains for consideration. It is not impossible that the sulphur supplied by the ammonium sulphate may have had some effect on the crop growth, as has been demonstrated in other countries, in particular New Zealand [11]. Before making final conclusions between ammonium sulphate and sodium nitrate, it will be necessary to test the effect of sodium nitrate on the reaction of the soil and on the availability of other nutrients, particularly micro-nutrients. It will also be necessary to determine whether crops in the area do benefit from applications of sulphur in the form of sulphate.

Little further can be offered by way of explanation of these interesting findings until much more experimentation extending over several seasons, in the field and in the laboratory, has been accomplished. The more fundamental aspects no doubt call for investigation in the microbiological field before a true insight into these phenomena can be achieved.

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NOTE ON A METHOD FOR SAMPLING GREEN CROPS FOR DRY-MATTER DETERMINATION

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WITH PLATES 11 AND 12

Summary

A method is described for the sampling of green crops for dry-matter determination and chemical analysis in which the green material is passed through a mechanical chopper prior to sampling. The method is rapid and gives a low sampling error.

INVESTIGATIONS on green crops such as cabbage, kale, maize, and rape often demand the determination of the dry-matter content and chemical analysis of the green material harvested. In practice such dry-matter determinations are usually made in laboratory drying ovens using samples of green material of about 1,000 grammes in weight.

Although in variety trials of green crops various plot sizes are employed, these are usually of not less than 6 square yards harvested area. Plant numbers and yields of green material vary considerably in different crops and under different conditions; but with a crop such as kale even a plot of 6 square yards is likely to consist of about 100 plants providing approximately 100 lb. of green material. Thus the dry-matter determination will be made on a sample consisting of only 1 to 2 per cent. of the produce.

It has been usual practice to take a random sample of five to ten plants to form a composite sample from the plot, the equivalent of about 5 to 10 per cent. of the total; these plants are chopped by hand or machine, and the chopped material sub-sampled to obtain the small quantity required for drying [1]. The method is laborious and liable to bias in sampling due both to the personal factor and the variability in plant material.

With the expansion of variety investigations on green crops at the National Institute of Agricultural Botany it became imperative to evolve a more reliable as well as a less laborious technique. Moreover, a more critical sampling method and one less subject to bias in sampling was desirable. To a large extent these requirements have been met by the development of a method whereby the produce is mechanically chopped prior to sampling.

In 1953 a chopper and cutter* was used on a silage-maize trial at Cambridge. The green material from each plot after weighing was passed through the machine and samples for drying were taken from the chopped material. These samples were taken with no especial care but before sampling the material was passed through the machine twice to ensure adequate mixing. In a typical trial, the duplicate samples taken

* Robust Chopper and Cutter Model RN 30.

[Empire Journ. of Exper. Agric., Vol. 26, No. 104, 1958.]

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from each of twelve plots showed a standard error, expressed as percentage of the mean, of 5·6 per cent.

The machine now being used is a similar model mounted on a trailer complete with petrol engine, so that the unit is mobile. Slight modifications have been made such as the fitting of supports to ensure stability, and extension of the delivery plate beneath the chopped material exit. In addition, large galvanized-iron containers are used to collect the chopped material; they are of a truncated-wedge shape to facilitate the feeding of chopped material into the machine for the second chopping (Figs. 1 and 2; Plates 11 and 12).

Further tests have been carried out and the results of these on a marrow-stem kale crop are given in the table below. The harvested-plot size for each treatment was 6 square yards. Four different methods were investigated: once-chopped and twice-chopped; these treatments being sampled by two methods, as a single complete sample and as a composite sample consisting of six smaller sub-samples. The whole of the material from each plot was successively sampled until none remained, which enabled the true dry-matter content of the whole to be calculated.

Mean Dry Matter as Percentage of Green Weight of Chopped Material, and Mean Protein Content as Percentage of Dry Weight

Treatment		Number of samples	Dry-matter content, %				Protein content, % of D.M.			
			Mean	S.E. of samples ±	S.E. as % of mean ±	Range of samples	Mean	S.E. of samples	S.E. as % of mean	Range of samples
Chopped once	Bulk sample (A)	13	15·2	0·26	1·7	14·8–15·6	10·0	0·36	3·6	9·2–11·4
	Composite sample (B)	18	13·9	0·23	1·7	13·5–14·4	11·1	0·17	1·5	10·9–11·5
Chopped twice	Bulk sample (C)	12	14·3	0·54	3·8	13·0–14·9	10·4	0·11	1·1	10·2–10·6
	Composite sample (D)	16	14·5	0·16	1·1	14·2–14·7	10·3	0·11	1·1	10·2–10·5
			Pooled sampling error = 2·2% of mean				Pooled sampling error = 2·0% of mean			

The marked variation between the plots which was evident in the field is reflected in their mean dry-matter and protein contents. The higher standard error for treatment C may be partly due to the atypical figure for the final sample taken, and also to the lower yield of this plot and the consequently lower number of samples taken. The protein-content data suggest that the double chopping has ensured a better mixing of the leaf and stem fractions, between which a considerable difference in protein content may be expected. The standard error for treatment D is very low and the twice-chopped composite-sample method has been adopted.

During the last four years this type of machine has been used success-

FIG. 1. Robust chopper and cutter showing collecting container in position

FIG. 2. Feeding chopped material into machine for second chopping

FIG. 2. Feeding chopped material into machine for second chopping

fully in sampling a variety of crops including cabbage, kale, maize, as well as the 'tops' of sugar-beet and mangels and separate leaf and stem fractions of kale. In addition, it will deal with root crops such as mangels and swedes; with these, however, coring is adopted as a more convenient method as cores appear less liable to soil contamination and fermentation.

The mechanical chopper provides a rapid method of obtaining samples of green crops for the determination of their dry matter and chemical analysis. The samples obtained by this method are highly representative of the field crop, even for those crops which show wide variation in the composition of the different parts of the plant, such as leaf and stem of kale and cob and stover of maize. Moreover, the sample material is in a form very suitable for oven drying.

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